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AUTHOR Huifen, Duan; And Others
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ABSTRACT

This publication consists of two reports that were commissioned by the United Nations Educational, Scientific, and Cultural Organization as background for its biennial report on world education. The first paper, "Educational Psychology and Teaching Methods in China: Developments and Trends," by Duan Huifen and others, indicates that educational psychology in China began with the introduction of theories from abroad. This was followed by a period of testing, assimilation, and thorough investigation, and finally by actual creative development. A distinctively Chinese school of educational psychology has yet to be developed, but one trend is the emphasis on the harmonious development of the whole personality. The second paper, "Trends and Developments in Educational Psychology in the United States," by Rochel Gelman and Meredith Gattis Lee, emphasizes recent interest in the constructivist nature of learning, a view that is currently in favor. Notions of learning as a process of building associations are being expanded in examinations of the active construction of knowledge. (The first paper contains 60 references, and the second, 121 references, many of which are annotated.) (SLD)

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* E = English, F = French, S = Spanish, R = Russian, A = Arabic.

Recent trends and developments in educational psychology: Chinese and American perspectives

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Preface

This publication consists of two reports which were commissioned by UNESCO in 1992 as background papers for the Organization's biennial *World Education Report*.

The first report, originally entitled Educational Psychology and Teaching Methods in China: Developments and Trends, was commissioned from the National Commission of the People's Republic of China for UNESCO, which arranged for it to be prepared by a team of specialists based at the Shanghai Educational Science Research Institute, China.

The second report, originally entitled Trends and Developments in Educational Psychology in International Perspective, was commissioned from the International Union of Psychological Science (IUPS), which aranged for it to be prepared by Professors Rochel Gelman and Meredith Gattis Lee of the University of California at Los Angeles, United States of America.

UNESCO is grateful to both the National Commission of the People's Republic of China for UNESCO and IUPS for their co-operation. In publishing the two reports, the Organization considers that they merit the attention of a wider audience interested in recent trends and developments in educational psychology.

It should be noted that the opinions expressed in the reports are those of the authors and do not necessarily represent those of UNESCO.

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Educational psychology and teaching methods in China: developments and trends

Duan Huifen, Zhang Shengyuan, Wu Zenqiang, Shen Zhifei and Xu Mangdi, with guidance from Qian Zaisen and Hu Xinghong

Background

Following a period of stagnation in the 1970s, educational psychology in China has in the past ten years resumed development. Current research covers a broad range of subjects. Many dissertations have been published and some noteworthy achievements have been made. According to the current statistics of five psychology periodicals published in China (*Xinli Xuebao/Acta Psychologica Sinica, Xinli Kexue Tohgxun/Information on Psychological Sciences, Psychological Development and Education, Explorations in Psychology* and *Trends in Psychology*), of 2,280 articles published in the past ten years, 750 (32.89 per cent) were on child development and educational psychology. Some of these articles were about experimental research on non-Chinese theories that had been introduced and tested. An even greater number concerned research undertaken in psychology, moral psychology, the psychology of teaching various educational disciplines, differential psychology and other areas.

Pan Shu's *Educational Psychology* (1980) was the first original treatise on the subject by a Chinese scholar to be published in China since the founding of the People's Republic. It gives an account of achievements in the field of educational psychology in the West and in the Soviet Union – including Edward L. Thorndike's educational theories, the Gestalt theories on education, B. F. Skinner's operant conditioning theory, J. S. Bruner's *The Process of Education* and Zankov's experiments in educational reform. Zhang Dexiu's *Research on Educational Psychology,* published in 1981, gives an account of American achievements in educational psychology research. It covers subjects such as the foundation and dynamics of learning, the learning and teaching processes, the development of thinking, personality formation, the measurement of intellectual aptitude and the evaluation of scholastic achievement.

During this period, various monographs and teaching materials by foreign authors on educational psychology were published in translation. These include *Educational Psychology* by Ohachi Masao of Japan, *Educational Psychology* by T. M. Saurey of the United States (4th ed., Boston) and *Educational Psychology in the Class-*

room by H. C. Lindgren (5th ed., London, John Wiley & Sons, 1976).

Even more articles presenting the most influential theories and research findings from abroad have been published in specialized psychology and education journals. These include articles on J. Piaget's theory of genetic epistemology and his concept of the stages of development of intelligence in children, J. S. Bruner's theory of cognitive discovery, D. P. Ausubel's theory of cognitive assimilation, B. S. Bloom's mastery learning, R. M. Gagne's theory of accumulative learning, Vygotsky's proximal zone theory, the humanist theories of C. Rogers and Abraham Maslow, A. Bandura's social learning theory and Lawrence Kohlberg's theory on the stages of moral development. Among these different schools of thought, the cognitive and humanist theories have had a very wide-ranging influence on educational psychologists in China as well as on educational practices in the schools.

Of the cognitive theories, those of Piaget have had the most significant influence in China. According to statistics kept by China's main psychology journals, Piaget's theories and research were the topic most frequently written about in the 1980s, being presented and discussed in several dozen articles.

J. S. Bruner's *The Process of Education*, translated in 1979 by Shao Ruizhen's research team, stresses the discovery method of learning and emphasizes the importance of the learning process and the pupil's initiative. These factors are acknowledged to affect the development of the pupil's intellectual aptitude, and Bruner's book has become one of the chief references for primary and secondary classroom teaching. Shao Ruizhen published *Educational Psychology – Principles of Learning and Teaching* in 1983 and *Educational Psychology* in 1988. He also published a number of other monographs during this period. In addition to presenting and examining selected theories that have had a major impact abroad, Shao provides a systematic introduction to Ausubel's theory of cognitive assimilation, which emphasizes meaningful symbolic learning for pupils in the school situation and the concept of reception learning. This theory has had a major impact on teachers' practices. Teachers have applied Ausubel's and Gagne's theories on learning to education design. They have tested these ideas and begun to incorporate them into applied research on the reform of primary and secondary education. These ideas have been found to be positive and meaningful in terms of helping teachers to choose appropriate methods of instruction, helping pupils acquire sound cognitive structures and developing their ability to transfer learning.

In *Mastery Learning*, Bloom asserts that effective education should guarantee that the majority of pupils are able to master the main content of course material and that with adequate time (learning opportunity) and appropriate teaching, the majority of pupils should be able to achieve the main learning targets. To promote mastery learning, he recommends 'diagnostic evaluation' and 'formative evaluation' – to ensure that as children apply themselves to their studies they will be able to achieve maximum development of their intellectual potential. Bloom's theory of learning is changing the views and methods of teachers in China, and its application has resulted in considerable improvements in scholastic results. Bloom's emphasis on the need to give every pupil full opportunity for learning, and to set different goals and requirements for cognitive, emotional and action skills in keeping with the needs of different types of pupils, has also had a strong impact.

The humanist school, represented by Abraham Maslow and Carl R. Rogers, emphasizes the individual's inner needs and the realization of his natural goodness and creative potential. The affirmation of the individual's own personality is at the core of this theory, according to which 'the human personality, when freely allowed to follow its course, is constructive and trustworthy'. This theory thus advocates pupil-centred education with an emphasis on affection and helping within caring interpersonal relationships. Rogers recommends a non-prescriptive approach to teaching and stresses the importance of an equal, cooperative relationship between teacher and pupil, based on sincerity, acceptance and understanding. The teacher's role is to assist, not to manipulate. These ideas – in particular the emphasis on the development of the pupil's personality and the need to give free rein to his latent abilities

– constitute something of a challenge to traditional education and have had a major impact on Chinese educators.

John Dewey's educational theories have had their ups and downs in China, being rejected totally until the 1980s. After that, there was a tendency to concentrate on the more rational elements of these theories. Dewey's notion that education must begin with the needs and interests of the child, the concept of the interplay of thinking and doing in learning, the principle of raising and resolving questions through thought, and the testing of results through doing have been positively received.

In the 1980s, Chinese educational circles were introduced to the works of the Soviet educator Sukhomlinski. These works were much translated and for a time were very fashionable. Sukhomlinski basically belonged to the humanist school of educational psychology and was deeply marked by Dewey's ideas on education. Although the influence of humanist ideological trends in education and Dewey's ideas on education may not have been as deep as that of some of the educational psychology theories that came later, in terms of the development of educational psychology in China it can be said that their influence has been far more extensive than that of any of the other theories.

In addition to introducing and assimilating educational psychology theories from abroad, educational psychology in China has been shaped by traditional Chinese ideas on psychology. For a long time, in China and elsewhere, there persisted a completely mistaken theory that psychology as a field of study did not exist in China. However, in the past ten years, cultural experts and psychologists have worked together to begin uncovering, understanding and systematizing Chinese theories on educational psychology from the early Qin dynasty up to the present. They have also conducted research from a cultural comparison angle, exploring the differences between indigenous Chinese psychology and Western psychology, and the specific features of each. Although much remains to be done in order to establish a systematic, indigenous Chinese psychology, there is no doubt that this work will have an immeasurable impact on Chinese educational psychology and indeed on educational psychology throughout the world.

Like Chinese medicine, indigenous Chinese psychology is based on visceral manifestations (state of internal organs), the network of main and collateral channels through which vital energy circulates, and the principle of *qi*. The heart is recognized as one of the five internal organs. The heart's *qi* drives the blood through the veins and arteries, and at the same time stores the mind's energy. The heart is a major, basic channel of mental activity. *Qi* thus affects the heart's activity as well as the five sense organs. *Qi* is what makes the ears hear, the eyes see and the heart beat. Without *qi*, there can be no thought, no knowledge, no interest. The notion of *qi* as influencing seeing, hearing, thinking and the heart means that it has no equivalent in the West. Other concepts, such as 'listening with the heart', 'listening with *qi*', 'inner vision', 'inner hearing', the 'heart's room' and 'transcendental meditation' are all the more unfathomable from the point of view of Western psychology.

Besides placing a great deal of importance on the heart's intelligence and decisive role, the ancient Chinese had an awareness of matters to do with the development of people's latent psychological abilities long before the Human Potential Movement, which did not emerge in the West until the 1960s.

In indigenous Chinese psychology, body and mind are integrated into a single theory and a healthy mind is considered just as important as a healthy body. Moreover, in accordance with the general notion of the mutually restraining five elements, the standard of psychological health is defined as the harmony of yin and yang, and of the five elements. True psychological health, therefore, is not characterized by great joy or strong feelings, but by a sort of general equilibrium of the emotions. On the basis of this, the ancients advocated mental self-regulation, so that through one's behaviour and habits the seven emotional factors (joy, anger, melancholy, brooding, sorrow, fear and shock) and the six desires could be kept under control, and one's psychological state could be kept in balance. This theory of the integration of mind and body, which values harmony and stresses self-care, is being mastered

by more and more school psychology counsellors, and a combined Sino-Western model for psychology in schools is gradually taking shape.

Education in ancient China emphasized moral education and morality was considered to be at the heart of knowledge. This model tended to emphasize an abstract, overall grasp of knowledge through emotional experience, while comparatively neglecting the training of the intellect and formal logic. In education, the principle of awareness was considered important, as were introspection and self-analysis. The unique pedagogic methods of ancient times are manifested in a technique whereby direct perception of ideas by the senses leads to the suggestion of another, symbolized significance. When applied to the teaching of language, this technique is very effective in producing analogies and in inspiring students to draw inferences.

However, in ancient China, studying meant careful, intensive reading, with the number of readings being equated with the depth of learning. Indigenous Chinese educational psychology is a product of an accumulation of elements and is rooted in the mentalities of the ancient Chinese peoples. Many lessons can be drawn from these ideas. Not only are they frequently reflected in teaching in the schools, but they have permeated education in the home, public opinion, the media, etc. They still, however, need to be thoroughly investigated and scientifically systematized.

Recent trends

Just as educational psychology theories have developed over the past ten years, progress has also been made with regard to research methods. The principal methods now used are the experimental method, the survey method and theory analysis. The survey method has developed quite rapidly and is being used on an increasingly wide scale. Rapid progress is also being made with regard to statistical methods. There are fewer and fewer research reports which do not provide statistics or which give only descriptive statistics and the use of deductive statistics is becoming increasingly the norm. There is also a clear trend towards the use of pluralist statistics. At the same time, the methodological aspects of educational psychology research are being explored.

In the past ten years, Chinese educational psychology scholars have undertaken a great deal of significant and creative research. Research topics include the psychology of teaching, moral psychology and differential psychology. Comprehensive research has also been conducted in the context of general educational reforms. This research mainly concerns research on the teaching aspect of educational psychology, research on moral psychology, research on differential psychology and cognitive research linked to general educational reform.

Research on the teaching aspect of educational psychology

Educational psychology in the teaching of mathematics

Lu Zhongheng's experiments in mathematics self-learning are based on his research on Skinner's principle of programmed learning. He compares the characteristics of the classroom system with those of individual instruction and proposes a (guided) self-teaching method geared to the Chinese context. He draws from the principles of 'programmed learning' as well as from the teaching experience of some outstanding teachers and proposes nine psychological principles, of which 'appropriate pacing' and 'immediate knowledge of results' are examples.

Based on the algebra textbooks used in secondary schools, he has written self-teaching materials for junior high school mathematics courses, including a textbook, an exercise book and a quiz book. On the basis of the learning process, learning goals and the psychological characteristics of learning, Lu has formulated seven principles of guided self-learning, among which: the combination of group teaching and individual teaching; the primacy of pupil self-learning with coaching by teachers; the implementation of a classroom model of awakening – studying – practising – knowing – self-learning, etc. These form the basic method for teaching and learning as well as the guiding principles of this method. Instruction

is geared to the development of pupils' knowledge and aptitude, as well as to individual differences, so that pupils are interested and motivated. This method is more powerful and more concentrated than traditional methods. Its effectiveness is particularly clear in terms of retention of material learned, improvement of creative thinking, scholastic achievement, improvement of self-learning aptitude and transference of learning to other academic subjects.

The research also deals with pupil typology with regard to learning. According to the author, the pupils who reap the greatest benefit from 'guided self-learning' are those who are 'steady rather than quick'; the 'quick rather than steady' types get less out of this method. The first exploratory experiments in guided self-learning were conducted in 1965 at the junior high school level. By the early 1980s the experiments had been extended to cover a broader scope. Today, more than 5,000 classes in 28 provinces and cities throughout the country are involved. In 1985, these experiments were awarded the Chinese Academy of Science's second prize for major achievement in scientific research.

Liu Jinghe's contemporary experiments in mathematics teaching in primary schools explore the development pattern of mathematics cognition in primary-school children. They draw on Piaget's theories on the development pattern of thinking in children, as well as on materialist dialectics. From his research on children's basic concepts of 'number', 'type', 'multiplication and division', etc., he systematically investigates children's cognitive development in terms of their conception of part–whole relationships and proposes twelve targets for part–whole relationship cognition. He also proposes revising the way in which mathematical knowledge is currently structured in primary schools, by using '1' as the basic standard and making 'part–whole relationship' cognition the main thread in mathematics teaching in order to mould sound cognitive structures in children and encourage the beginnings of dialectical thought.

A research group has written a set of teaching materials entitled *Contemporary Primary School Mathematics,* which has been used experimentally in the classroom since 1981. Several cycles have already been completed, and the teaching results have been very good. Some 2,500 classes in 28 provinces and cities throughout the country have taken part in the experiment.

Research on educational psychology in the teaching of language, chiefly focused on teaching character recognition and reading ability

The teaching of Chinese characters in primary school is the subject of a long-standing conflict between two teaching methods: the 'decentralized' method and the 'concentrated' method. According to the findings of previous psychological research, there is something to be said for each of the different methods. Provided one does not go against children's psychological characteristics and as long as the conflicting relationship among the three components of Chinese characters – sound, form and meaning – is properly grasped and the main contradictions highlighted, then the objective of improving character-recognition results can be achieved. In the post-1980s, an experiment aimed at reforming language teaching (phonetic character-recognition for earlier reading and writing) was conducted. The first stage consisted of intensive study of the Chinese phonetic system (Hanyu Pinyin). This phonetic system was then used as a tool to get through great volumes of reading material. The idea was for reading and writing to develop simultaneously – for reading to 'look after' and advance writing. Psychology research shows this approach to be suited to the characteristics of children's cognitive development and appropriate to the psychological patterns of the way in which children learn Chinese characters. It links the three elements of character-recognition, reading and writing, thus forming an organic whole that is more complete, more orderly and more coherent. This system has effectively improved the quality of teaching and helps develop pupils' intellectual aptitude. The research launched in 1982 in three cities of Heilongjiang Province has been extended to several thousand schools in twenty-three provinces, cities and autonomous regions.

Wan Yunying has conducted long-term research on reading ability. The main subject of this

research is the cultivation of primary- and secondary-school pupils' independent reading ability. According to the research findings, the topic sentence of a piece of writing and the characteristics of its literary form and structural pattern are the main external conditions influencing reading comprehension, and the reader's primary cognition and cognitive structures are the internal conditions affecting the achievement of reading comprehension and analytical skills.

Wan has also conducted research on reading-level evaluation and reading-aptitude structure. In *Factors – Behavioural Laws*, Mo Lei and others define the factors of reading-aptitude structure as language decoding, organization and linking, pattern differentiation, selective storage, feeling for language, transfer of reading, summarizing, evaluating, etc.

Research on moral psychology

Research on moral psychology was a comparatively weak area in China until after the 1980s, when genuine, systematic development of this field began. Some of the most outstanding research in this area concerns levels of development of moral judgement in children and the characteristics of this development. Research has also been done on the psychological structures revealed by pupils' moral behaviour and the relationship with educational conditions and methods. Other research concerns problem behaviour in pupils, methods for correcting it, etc. The most influential and representative studies include those described below.

Research by Li Boshu et al. on the development of moral cognition in Chinese children

This research was based on Piaget's and Kohlberg's theories of the stages of children's moral development, with reference to the Chinese context. A series of co-ordinated studies applying scientifically proven methods was conducted on a large sample of kindergarten, primary- and secondary-school children of varying ages. The research covered eighteen provinces, cities and autonomous regions throughout the country. The ten-year research project was divided into four parts:

1. Testing and revision of Piaget's model, with regard to moral judgement in terms of responsibility for one's behaviour, collective ideas, development of the concept of punishment, etc.
2. In keeping with the Chinese social context, exploring the development of some specific moral concepts of Chinese children, such as the concepts of public and private, collectivism, friendship, patriotism, love of labour, etc.
3. Cross-cultural research on children's moral development in China's different ethnic groups.
4. Research on intervention in children's moral development.

This research generally upheld Piaget's theory that moral reasoning in children evolves gradually, in stages. Although the ages at which the stages of development occurred did not always correspond to Piaget's findings, the phased nature of development was confirmed.

With regard to moral judgement in terms of taking responsibility for their behaviour and the development of the concepts of fairness and punishment, Chinese children were generally found to mature between one and three years earlier than Piaget had found. Because a larger sample was selected, some of the findings differed from those of Western research. Some of the moral concepts specific to Chinese children had never been studied by researchers in other countries and other concepts had been studied from a different research angle. This research makes a contribution to theories on the development of moral cognition in children.

Cross-cultural research comparing the development of moral judgement in the children of ethnic minorities such as the Mongols, the Zhuang, the Tibetans, the Uighurs, the Yi, the Miao and the Tu with the development of moral judgement in Han Chinese children reveal some patterns in the development of moral judgement in ethnic minority children, as well as the influence of specific cultural background and moral training on this development.

Research on intervention in moral development also confirm that praise and reasoning are more effective than praise and rewards in encouraging children to make intentional judgements, supporting Piaget's position that moral development is a process of natural change in thought structure.

The findings of all of these studies have provided a scientific basis for moral education in China.

Research by Zhang Zhiguang et al. on the psychological structures manifested by pupils' moral behaviour and the relationship with educational conditions and methods

This research draws on non-Chinese theories (e.g. A. Bandura's social learning theory) and applies measurement tools developed abroad. In relation to the Chinese context, the research explores the way in which external conditions penetrate internal psychological factors to play a role in forming and transforming moral character. This research covers three main areas:

1. Educational psychology experiments on the formation of moral character. These experiments, concerned with raising moral cognition, investigate the effects of moods and changes in value systems on moral judgement, and on the formation and transformation of moral behaviour.
2. Social psychology research on moral matters. This research explores interpersonal relationships and structures within the class group and their effect on individual moral development, and the circumstances in which shifts in role and position cause additional changes in the system of behavioural dynamics.
3. Surveys and summaries of individual educational experiences with problem behaviour. This research deals with manifestations and causes of problem behaviour by pupils as well as remedies for such behaviour.

Research findings of the past several years indicate that pupils' moral character is primarily based on their perception, knowledge and understanding of the moral models and norms of the outside world. Through practice and feedback (including self-restraint), moral character gradually forms and develops. The pupil's willingness to put what he has learned into practice depends on all sorts of internal conditions, including his innate 'cognitive-emotional' structure, value concepts, determination and other personality traits. External factors, including the form in which education on moral models and norms is provided, interpersonal relationships within the group, social environment, role and position, are also involved.

Research reveals the cause–effect relationships between these internal and external factors, and patterns of formation and transformation of moral character. The research method, which combines the general lessons of educational experience with psychological experimentation, is favourable to the selection of topics meriting testing and examination. Furthermore, research findings can be compared and contrasted with educational realities, and practical, feasible educational measures and recommendations can be proposed.

Research on differential psychology

Ten years ago, no research had been done in China on differential psychology. Since then, gradual development has taken place. Research conducted on the moral development of supernormal children, specifically with regard to individual differences, has filled in some of the blanks in Chinese research in this field. In 1978, a national, co-ordinated survey and tracking study was launched by Zha Zixiu's research team. At first, only five schools were involved, but the study was gradually extended to cover thirty-two schools. The research team's work consisted of:

A survey of 100 supernormal children and young people, of whom 50 were tracked.

A dynamic, comparative study of 5,000 normal children aged 3 to 15, covering analogical reasoning, creative thinking, power of observation, memory and other areas. The publication of *Tests for Differentiating the Cognitive Ability of Supernormal Children* established norms for use in testing the cognitive ability of supernormal children.

Comparative research on non-intelligence psychological traits in the personalities of supernormal children was conducted. This research produced the Non-intelligence Personality Traits Test Questionnaire.

Intensification of experiments in group education for supernormal children. Nearly thirty experimental classes for supernormal kindergarten, primary- and secondary-school children, plus more than thirty university classes for young people, were set up. These classes are intended to provide supernormal students with the right kind of teaching at the right time and to create

the conditions for educational intervention and in-depth research on the psychological development of supernormal children.

Research findings indicate that the differences between supernormal and normal children are not obvious in all aspects of cognition. Rather, it is in the most difficult aspects of thinking that these differences are most striking – for example, creative thought and numerical analogical reasoning. Differences between supernormal and normal children are manifested not only in levels of development and the speed at which development takes place; these differences show up in the developmental process, in the form development takes and in the specific characteristics of development.

Research indicates that the differences in the psychological structures of supernormal children are not limited to intelligence and creativity, but include some non-intelligence psychological personality traits. Supernormal children's development depends not only on their outstanding intelligence, but on non-intelligence factors and personality traits such as independence, love of winning and thirst for knowledge. The outstanding traits of supernormal children merely represent the potential for development; environment and education are the decisive conditions by which this potential is realized.

The findings described above provide a psychological basis for conducting research on special education for supernormal children and better education for normal children.

Measurements of the cognitive characteristics of children of low intelligence have also been carried out and research has been done on early intervention, training and other issues. Research has also been carried out on children of normal or above-normal intelligence whose level of scholastic achievement is low.

Comprehensive research linked to general educational reform

This is psychological research on topics such as educational theory and the development and training of the pupil's intellectual aptitude, based on long-term, in-depth study of educational realities and in close conjunction with educational reforms in primary and secondary schools. The most influential of these investigations include the four described below.

Feng Zhongliang's experiments in structured-directive education

The theory of 'structured-directive education' is the result of ten years of educational experiments thoroughly exploring the basic areas of teaching, learning, aptitude and instinctive moral character, and the assimilation of the findings of research conducted in other countries, e.g. the primary school system reform experiments by Zankov of the Soviet Union, the Galperin School's theory of controlled education, Bloom's concept of structured education (United States) and Gagne's accumulated learning theory.

According to the theory of 'structured-directive education', education must be focused on the pupil's ability and moral psychological structures, and on the implementation of directive training. The research is based on three theories (educational systematization and transfer of experience, acceptance and structuring of learning by the pupil, and analogous experience in terms of aptitude and character) and on five types of learning patterns (motivation for learning, transfer of learning, grasp of knowledge, skill-formation and acceptance of behaviour standards).

Feng recommends reforms in four areas of the education system (education targets, teaching materials, teaching activity and the scholastic results evaluation system) with a view to accelerating the formation and development of psychological structures and implementing directive training.

The findings of experiments with 'structured-directive education' indicate that it can substantially improve educational results. The experiments in primary-school teaching reform are based on two premises: first, that, without increasing time spent on lessons in the classroom and without increasing homework, two years' coursework can be completed in one year; and, second, that the quality of teaching is superior to that of the transfer method of teaching.

Lin Chongde's educational experiments on the development and training of psychological ability in primary and secondary school pupils

The core topic of this research, begun in 1978, is

the relationship between education, teaching and learning with the development of the pupil's intellectual aptitude and skills. The findings emphasize the importance of developing the quality of the pupil's thinking. Ten years of educational experimentation produced a specific system of theories and a number of standard conclusions on the development and training of intellectual ability in primary- and secondary-school children. Experiments are at present being conducted in twenty-six provinces, cities and autonomous regions.

Research in 'joy education' by the primary school attached to the Shanghai Teachers' College

In terms of orienting primary and secondary educational practices, the emphasis in Chinese educational psychology has shifted in the past ten years from the transfer of knowledge to the training of intellectual aptitude, and then to the fostering of non-intelligence factors and the development of the pupil's whole personality. Personality-based teaching has recently come to the fore. In 1984, the primary school attached to the Shanghai Teachers' College became the first school in the country to implement 'joy education'. With this personality-based teaching method, education begins with the emotions. Joy education emphasizes the need for the teacher to create a harmonious, relaxed educational environment so that pupils are able to participate actively and positively in the educational process. The teacher must also consider what children need for their physical and psychological development. These needs can be summed up as love, beauty, interest and creativity – the four key elements of joy education. At present, experiments in joy education have been extended to a number of primary schools throughout the country.

Research on 'success education' by Shanghai Number Eight Secondary School, Zhabei District

'Success education', initiated by Shanghai Number Eight Secondary School, Zhabei District, is yet another example of how educational psychology has guided educational practices. In success education, it is up to the teacher to create the teaching and learning conditions that will enable pupils who are having difficulties with learning to reap continual success – and thereby to alter their warped self-perceptions and improve substantially the quality of their education. Success-education experiments have been extended to many junior high schools.

Conclusions

The development of educational psychology in China began with the introduction of theories from abroad. This was followed by a phase of testing, assimilation and thorough investigation, and finally by actual creative development in China. The results of research carried out in certain areas in conjunction with educational reforms in China are particularly salient. These results can be said to constitute a contribution to the world-wide development of educational psychology.

However, research does not yet cover a very wide range of fields and if a distinctively Chinese school of educational psychology is to be formed, much research still remains to be done regarding the influence of various internal and external factors on educational phenomena and the comprehensive application of research methodology and multi-factoral analysis. The theories generated by research findings need to be summarized and generalized, and traditional Chinese educational psychology must be tapped. Many specific issues in education require more thorough research.

Looking back on how existing research and theories have influenced education and teaching, the need to train skilled people for the twenty-first century can be expected to produce some trends in educational psychology that will have a major impact on primary and secondary education and teaching methods.

The first of these trends is emphasis on the harmonious development of the whole personality. The acceptance of both cognitive psychology and humanist theories by Chinese educational psychologists illustrates the increasing awareness of Chinese educators of the need to consider the human being as an organic whole. In human psychology, it is impossible to separate knowledge, emotions, desires and actions. All of these things interact and promote one another. In both pure and applied research, the emphasis is on the patterns of the pupil's cognitive development, includ-

ing knowledge of knowledge, study tactics and study methods, as well as on the pupil's motivations, emotions, moral character, etc. Such trends are influenced by contemporary developments in psychology and are also deeply influenced by society's expectations for schools to train qualified people.

It is not enough for qualified people throughout the world to have knowledge and ability. If they are to meet future world challenges, it is even more important for them to have a sound moral character, a sympathetic heart, a sense of responsibility and a spirit of co-operation. Schools are therefore not merely places where knowledge is passed on. It is even more important that they enable pupils to learn the principles of conducting themselves in society – that they be places for 'learning to learn' and learning to be an upright human being.

The historic trends in the development of educational psychology, from educational philosophy to educational science to psychological science, inspired psychology historian Sir Cyril Burt to comment sadly in 1962 that, although psychology's original objective was to study man, in the 100 years since it was given over to science, first the human soul was lost, then the human heart was lost and finally, he added, even human consciousness will completely disappear.

Since the rise of humanist psychology in the 1960s and the renewed influence of cognitive psychology, there has been a general trend in psychology towards returning to the study of human nature (man's outward behaviour and internal psychological processes). At the same time, the trend in educational psychology has been towards a return to the schools and pupils' learning behaviour has once again become an important research topic. From now on, the goals of educational psychology will be to provide a complete, harmonious education for the pupil's whole personality and to develop all aspects of knowledge, emotion, purpose and behaviour.

The second foreseeable trend is the evolution of a specifically Chinese system of educational psychology theories, combining international and indigenous elements. Where the international element is concerned, constant discrimination must be exercised in assimilating foreign theories and research methods which conform to scientific standards. Psychology is part of the spiritual wealth shared by all of mankind and Chinese educational psychology must be able to reflect the direction in which international research is developing.

As for the indigenous element, psychology must develop in the direction of studying the native country, the native peoples and the native territory, in order to resolve the country's own real, indigenous problems. If one looks at all of the different theories and factions in the history of psychology, one sees that all of them, to varying degrees, reflect the spirit of a time, a people and a place.

Development must follow an indigenous orientation. All of the most influential research in educational psychology conducted in China over the past ten years, outlined above, has striven to fulfil this aim. In addition to unearthing traditional Chinese ideas on educational psychology and comparing and contrasting these ideas with theories from abroad, Li Boshu's monograph, *Moral Psychology*, gives an account of the findings of his own research in China. Lu Zhongheng's method for guided self-learning of mathematics in secondary schools stresses the cultivation of the capacity for self-learning. Liu Jinghe's research on modern primary school mathematics is about the beginnings of dialectical thought. In their investigations of pupils' psychological abilities and development, Zhu Zhixian and Lin Chongde look at things from the viewpoint of developing and training the quality of the pupil's thinking. According to Feng Zhongliang's structured-directive education, an integrated system of education is the starting-point from which the pupil's abilities and moral character can be structured.

All of these theories, which are inseparably linked to educational realities in China, are influencing teaching methods and contributing a distinctively Chinese element.

A third trend is the interpenetration of recent, developing disciplines. This is a major feature and an important trend of modern science. The findings of research in various other disciplines have influenced the orientations of educational psychology research. For example, brain-research findings on the asymmetrical functioning of the

two hemispheres of the cerebrum have revealed ways of developing the right brain so that the left and right hemispheres develop in a fully co-ordinated manner. These findings will have an impact on changes in teaching methods and classroom teaching models.

Computer science provides another example, with education technology applications: the product of the linking of artificial intelligence with educational science. The application of audiovisual techniques to educational psychology in the classroom has provided new topics for research. Computer-Aided Instruction (CAI) has broken the mould of collective classroom instruction. With this pupil-centred method of individualized instruction, the teacher guides and organizes instruction in accordance with pupils' individual differences. In Intelligent Computer-Aided Instruction (ICE), instruction is designed with emphasis on the organic link between the expert, the pupil and the teacher-guide, and on the need to impart knowledge in a way that is suited to the pupils' intellectual characteristics, existing knowledge and individual differences. In accordance with learning targets, the pupil's cognitive structure and feedback received from the pupil, the teacher adjusts teaching tactics in such a way as to achieve the best possible teaching results. It will therefore be necessary to conduct research on the learning process and on cognitive structure, cognitive tactics and cognitive processing in pupils. Research on teaching tactics, teachers' cognitive traits and style, etc., will also be required. In addition to research on pupils and teachers, research based on the principles of educational psychology should also cover curriculum, teaching materials, etc.

In brief, the intersection and combination of various disciplines will ensure that educational psychology research develops both in breadth and in depth.

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Trends and developments in educational psychology in the United States

Rochel Gelman and Meredith Gattis Lee

Introduction

Worldwide, children must acquire the skills required to flourish later as adults in their communities. More and more these skills include the diverse set of literacy tools that support informed interactions with the environments of print, numeracy, science, communication, markets, work and transportation. Developments in the psychology of learning offer some clues as to how the world community might proceed to help countries and their education systems meet these challenges.

The emphasis in this paper is on the constructive nature of learning, a view that is currently in favour. To place this position in perspective, we briefly trace the history of the field from associationism to constructivism. We use the constructivist paradigm to examine current trends in the study of knowledge and the study of context, and the interactions between the two. The search for contextual models of learning has led to close examination of group learning and cultural models of learning, such as apprenticeships. Cultural models and other factors have increased awareness of the multiple influences on knowledge structures and have led to new efforts to define and measure competent performance and out-of-school learning options. Contrasting trends in current research point to the importance of considering implicit forms of learning as well as explicit ones.

The historical study of learning

Our associationist roots

The question of how people learn has always been a fundamental one in both psychology and education. Until recently, accounts based on, or consistent with, associationist theories of learning have enjoyed centre stage. Indeed, they continue to figure centrally in most connectionist models of cognition and learning. Accordingly, it is not surprising that scholars are still concerned with understanding the laws that govern the growth in strength of associations, including the laws about practice, spacing, frequency, response-stimulus compatibility, etc. (see Anderson, 1990; Schmidt and Bjork, 1992). These investigations have yield-

ed reliable findings but, as Anderson notes, they are of limited generalizability. This is especially so when one considers educational applications. Another limitation is the difficulty of transferring the findings (Salomon and Globerson, 1987). As Brown (1990) has noted, the tradition of using materials and tasks that are simple enough to analyse in a laboratory has often left unanswered the question of how to apply the outcomes of such work to the learning of complex materials in specific subject domains.

The active mind

Psychology and education have witnessed a theoretical sea change in the last twenty-five years. Until relatively recently, almost everyone accepted the empiricist's thesis that human infants start with mental blank slates, upon which the records of experience are gradually impressed. The common assumption was that newborns cannot hear, see or smell, that they spend their first year of life in a blooming-buzzing confusion and that they lack the ability to form complex ideas about the world. True, babies certainly are born with notably limited response abilities and spend much of their early life sleeping. Still, they are not simply passive receivers of data that wash over their sensoria.

In fact, healthy infants will use whatever limited response abilities they have to explore – and even control – their environments as soon as they come into the world. We have known since the early 1970s that infants work (for example, by sucking) for the privilege of looking at something that interests them. Kalnins and Bruner (1973) showed that infants between 5 and 12 weeks of age learn to suck on a pacifier to bring a slide into focus and look at it until they are bored (that is, until they have habituated). They then let the picture go back out of focus – until there is a clue that a new picture might be on the screen, at which point they will once again get actively involved in adjusting the quality of their view. This study is but one of hundreds that tell us that babies have the motivation and the ability in certain cases to explore their perceptual world (Gibson and Spelke, 1983).

It is now known that infants even possess complex learning, thinking and interactive abilities. For example, during their first year, infants pay attention to number-relevant input as demonstrated by the inclination to match the number of drumbeats they hear with one of two slides that has the same number of items on it (Starkey et al., 1990). A similar early cross-modal mapping skill allows them to match a sad face with a sad voice (Walker, 1982). Their interest in and knowledge about three-dimensional objects is demonstrated by the fact that they are surprised by impossible events, as when one object seems to pass through another (Baillargeon et al., 1986). Such findings have led psychologists and educators away from the idea that infant minds are blank slates, incapable of complex learning and thought. Even though infants are preverbal, they participate actively and selectively in their learning about the world around them.

Similarly, from a very early point in their lives, children are motivated to persist with a task – seemingly on their own and without external reinforcement – until they have mastered some game, problem or area of knowledge. A famous example of this active involvement in learning comes from Piaget, who tells of his infant daughter's attempt to push a toy she was holding horizontally through the vertical bars of her crib. The opening was not wide enough, but she continued to try until, eventually, she began to rotate the toy. Soon thereafter she rotated it enough for it to pass through the bars.

Further examples of children actively engaging in cognitive activities on their own are seen everywhere now that we are paying attention to them. Karmiloff-Smith and Inhelder (1974/75) describe one such case. They offered preschool children repeated opportunities (over several sessions) to balance each one of a set of blocks on top of another block. Some of the blocks had concealed weights and therefore did not balance at their geometric centres. Initially the children succeeded at balancing each block, no matter what kind it was, by using a combination of trial and error and brute force. When a trick block fell, a child moved it around while pushing down on it until balance was achieved. After repeated opportunities to play with the blocks, children started to behave as if they were systematically applying a 'blocks bal-

ance at their midpoint' hypothesis. As a result, they now started to make errors with the trick blocks. These they placed aside, saying things like, 'don't work'. Of special interest is the fact that there came a time when children changed their strategy again, in a seeming effort to find an all-inclusive solution. *On their own* they came to realize that they would have to use a third block as a counterweight for blocks that they could feel would not balance at their geometric centre. Therefore, they were once again able to balance all blocks. It is important to highlight the fact that these children gave up the trial and error solution that worked in favour of a more systematic one. Had they not done so, they would not have generated the negative data that eventually encouraged them to find a yet more advanced solution.

This motivation to explore, even to work to explore, and then to master what is of interest is indicative of more general facts about the human mind. Learners are inclined to attend to things that they know something – as opposed to nothing – about. Second, they interpret what they encounter with reference to what they already know. Finally, there are at least some times when self-motivated exploration leads one to learn new things on one's own. Kuhn (1970) suggests that thought experiments are most likely to occur when a hypothesis has been tried exclusively long enough to generate outcomes that do not fit an initial hypothesis. This, he continues, yields one condition for learning, which is the need to resolve the conflict by finding a consistent account of all the data.

All of the above is consistent with Bartlett's and Piaget's idea that knowledge is constructed by the learner, and it fits well with the strong theoretical commitment to some form of constructivism in a number of research centres around the world (see Glaser, 1991, and McGuiness and Nisbet, 1991, for reviews from the perspectives of the United States and Europe, respectively). Of course, these characterizations of children as active explorers and self-motivated learners take as given that the children are well nourished and free of disease. Even the relatively brief period of food shortage that occurred in Kenya during the 1984 drought influenced these active-learning tendencies in Embu schoolchildren: an ongoing longitudinal study of the effects of malnutrition on development made it possible for McDonald et al. (in press) to observe a drop in school-aged children's attentiveness during school tasks and a drop in activity in the playground. Although attentiveness rebounded once the food shortages abated, play activity did not.

The structured mind

The tendency actively to seek out, select and interpret inputs goes hand in hand with another important fact about the mind. This is that human beings develop organized knowledge bases. We are not all that good at remembering a collection of random inputs and are far better able to remember that which is organized, especially if we impose the organization on the information ourselves (Mandler, 1984). This means that coming to understand and know is as much an active process as is attending to the world. Indeed, to the extent that we already have knowledge in an area, it is easier to find yet more things that are related to this knowledge and therefore to learn even more about what we already know. We actively use what we know to make sense of our interactions with the environment. Put differently, knowledge can help make some aspects of the environment more salient than others. It can even alter our interpretation of that environment. For example, it takes training as an archaeologist to see that something lying on the sand at an archaeological site is a piece of old bone. The same object might not even be noticed by the untrained eye (that is, it would not be salient) and, if it were, it would probably be interpreted as just another stone.

Other trends have fed the growth of attention to a more cognitive approach to learning. These have included the reintroduction of the study of attention as a centrally controlled process (see Shiffrin, 1988, for a review), the uptake of the computer metaphor of mind, following successful efforts to use computer models for complex activities (Newell and Simon, 1972) and the growing appreciation of Piagetian theory as well as of other structural accounts of mind (for example, Chomsky, 1965). Subsequent demonstrations of the centrality of knowledge-rich structures (for example, Chi and Ceci, 1987) have led cognitive,

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developmental and educational psychologists to work on structural descriptions of different knowledge states and to recognize learners' tendencies to relate novel inputs to what they already know. Understanding the organization and structure of knowledge and its impact on learning have become the central goals of psychological investigations of learning, both in and out of school settings.

Research concerning the nature and organization of knowledge and how it influences further learning has moved to the forefront in many countries, possibly because empirical progress in this area can inform the teaching of complex bodies of knowledge. We now know that the ability to form organized knowledge bases and to use related structures provides learners with powerful storage, retrieval and transfer tools. Structures serve as memory organization devices for keeping together related material, even if the material is not yet well understood. Mental structures also support inferences and, therefore, transfer. For example, if we are told that something called an *Echidna* is an animal, we can access our memory about animals to find information that can be transferred to this new case. Doing so allows for the inference that an *Echidna* eats, breathes and moves by itself, even if we have never seen or learned about one in our entire lives.

Theoretical descriptions of knowledge states vary along two continua. The first dimension pertains to the units of analysis that theorists emphasize. Two classes of models in which this dimension is considered are information-processing models and structure-specific models. In general, the former emphasize general process notions such as processing speed, short-term memory, connections, long-term memory, etc. (for examples, see Anderson, 1990, and Halford, 1989). The latter emphasize structures and mental models, although they vary as to whether they make use of domain-general structures like logical ones or more domain-specific, content-relevant structures, rules or mental models. The second dimension of theoretical descriptions of knowledge states pertains to whether contexts are given a central role in the theory and, if so, to what extent context is emphasized. The wide range of researchers who are concerned with context are particularly influenced by Vygotsky and his focus on the socio-historical-cultural settings for development and/or his concern with metacognitive skills.

Some theorists' concerns fall at the intersect of points on the above dimensions. Others focus their efforts exclusively on one of the issues captured by the outline. For example, Case (1985), Halford (1990) and Siegler (1991), who are often dubbed neo-Piagetian, combine information processing and Piagetian theory. Lave and Wenger (1991) focus almost entirely on the effect of contexts, so much so that they resist efforts to make generalizations about learning across settings. Others prefer to appeal to the different mental models or structures and/or the related action goals that organize content domains (for example, Brown, 1990; Carey and Gelman, 1991; Karmiloff-Smith, 1992). Although there are significant theoretical consequences associated with these different choices, most are committed to the idea that concept acquisition involves the building of structured or complex knowledge systems as a function of learning opportunities. Coherent mental structures enable inference-making and understanding.

The constructivist mind in education

Since constructivist inclinations are at least as characteristic of children as they are of adults (Mandler, 1984), the shift from the model of learner-as-depository of inputs to a model of learner-as-active-interpreter of inputs has important implications for education; in particular, we can no longer assume that children start school with little if any knowledge of the topics we propose to teach. Children start building organized representations of their social and non-social worlds early in development. What they have already learned, usually in informal and implicit ways, is used to interpret what they encounter in the classroom and in other settings in their lives. This means that what we teach is interpreted, not just absorbed, even at the beginning of school. Therefore, we need to consider what assumptions, beliefs and knowledge children bring with them when they start school (for example, Carey, 1985). Although knowing something about a target topic can facilitate further learning, it need not. In fact, what the learner and

teacher assume or know can form barriers to the instructional goals of schools. This can happen for several reasons.

First, children start developing naïve theories about the world they interact with before they start school (Carey, 1986; Hatano and Inagaki, 1987; Keil, 1989). For example, Hatano and Inagaki showed that 5- and 6-year-old children in Japan knew enough about animates to answer that they could not keep a baby rabbit small forever because it would grow as it ate more and more. Similarly, comparably young children in various countries develop a principled understanding of counting (Gelman, 1982; Resnick, 1989). Gelman and Meck (1986) report that 3- and 5-year-old children are able to distinguish standard left-to-right counts of a row of items from novel but correct counts, for example, one that starts in the middle of a row and comes back around to the beginning of the row. Researchers repeatedly find that children invent solutions to addition problems. The following from Carpenter and Fennema (1989) is illustrative:

> A first grade student (about seven years old) was asked to add 246+178. He responded: 'Well, 2 plus 1 is 3, so I know it's two hundred and one hundred, so now it's somewhere in the three hundreds. And then you have to add the tens on. And the tens are 4 and 7. . .well, um, if you started at 70, 80, 90, 100. Right? And that's four hundreds. So now you are already in the hundreds because of that [100+300], but now you're in the 400's because of that [40+70]. But you've still got one more ten. So if you're doing it 300 plus 40 plus 70 you'd have four hundred and ten. But you're not doing that. So what you need to do then is add 6 more onto 10, which is 16. And then 8 more: 17, 18, 19, 20, 21, 22, 23, 24. So that's 124. I mean 424'.

These understandings can support problem-solving and the invention of further learning but can also impede them. Although knowledge about counting and its relation to addition supports learning about addition and subtraction with the positive natural numbers, the same knowledge can impede learning why fractions are numbers. Fractions are not the kind of thing one gets via counting (formally they represent the result of one number divided by another). Yet this mathematical truth does not keep children from interpreting their lessons as novel opportunities to apply their firm beliefs about the counting numbers. Many 8- and 9-year-old children tell us that 1/76 is more than 1/56 because 76 is a bigger number (Gelman, 1991). Although further instruction about fractions leads to some accurate learning about certain facts (such as $1/2 > 1/4$), the tendency for children to assimilate the data about fractions to their notion that all numbers are the result of counting persists for a long time. It is well known that students all over the world have difficulties mastering the mathematical concepts that are related to the fact that fractions (more accurately, rational numbers) are true numbers. Well into secondary school, robust tendencies remain for pupils to order both fractions and numbers with decimals as if they were natural, whole numbers and for students to insist that the product of two fractions must be greater than either of the separate fractions (Fischbein et al., 1985).

Just as children form naïve theories from observations of the physical world and from experience with certain practices before they enter school, they similarly acquire implicit cultural and sociolinguistic knowledge from their community (for example, Bernicot and Makrokhian, 1989; Schieffelin and Ochs, 1986; Weisner, 1984). And again, the knowledge that children bring to the school setting has the potential both to help and to impede their performance on academic tasks. Cultural and sociolinguistic knowledge influences how children interpret the school setting, their sense of place, their ability to do well in school, the way people talk to them and so on. Often there is a match between the assumptions children bring to school with them and the learning-teaching goals of their schools. But this need not be the case (Cazden, 1988). For example, certain cultures and families do not encourage young children to 'show off' by answering questions to which adults certainly know the answers. Children growing up in such environments are at disadvantage in schools in the United States, the United Kingdom and Australia where a favourite pedagogical technique involves asking questions which have obvious and concrete answers (Siegal, 1991). Imagine the situation when a first-grade teacher asks: 'How much is 1+1?' Children who have not learned the sociolinguistic rule that allows for answering an obvious question may remain quiet (Heath, 1981). Their failure to answer is unlikely to be due

to a lack of knowledge; still, it will be so interpreted and therefore will reinforce expectations that these children will not do well in school. Just as the culture-specific pragmatics of language can pose problems for knowledge acquisition, so can natural language as a whole. Children's knowledge of a natural language can interfere with their learning the language of mathematics. For example, 'multiply' has different meanings in English and in mathematics (Orr, 1989).

These considerations bear on assessments of competence and make it clear that competence is a multifaceted attribution. No longer can we focus simply on the question of what an individual knows about reading, mathematics, problem-solving, etc. For no matter how deep their knowledge might be in these domains, the display of it takes place in different settings. Knowledge may be shown in some settings but not others. Whether transfer from one setting to another will occur depends on at least two variables: general thinking skills (especially the kind that are called 'metacognitive', such as monitoring one's progress and evaluating strategy success and understanding) and interpretation of settings (recall the problem that might occur if the school setting is misinterpreted as one in which obvious, concrete questions are not answered).

Interpretations of settings depend upon knowledge and language use, people's attitudes and beliefs, institutions and so on, such that mismatches on any of these dimensions can interfere with displays of conceptual competence (Elbers, 1991; Gelman and Greeno, 1989). So impressed are some theorists by the effects of situations on performance levels that they argue that every situation is unique unto itself and that it is premature to attempt to establish principles about learning and its transfer (for example, Lave and Wenger, 1991). We do not go this far; rather, for reasons considered below, we share with others (for example, Brown et al., 1993; Perret-Clermont and Schaubler-Leoni, 1989) the view that one can take the social and cultural knowledge of a community into account and still reach some generalizations about possible future directions for our schools.

There is a paradoxical fact about the claim that the young are active knowledge constructors. This statement implies that the motivation to learn and successful learning are part of the same acquisition mechanism, a view that will be recognized as very Piagetian. Yet, educators worry a great deal about the lack of motivation they see in students and are concerned about finding ways to foster or re-ignite the cognitively based motivation that is so prevalent in very young children (Stipek, 1988). An important step in this process involves identifying how characteristics of the teachers, students, classrooms, lessons and learning interact to influence student motivation (d'Ydewalle, 1987). Developmental, cognitive and cross-cultural studies of teaching style, classroom goals and lesson content not only inform us about different cultural instantiations of such influences, but they also allow us to determine how their variation may affect student motivation levels. For instance, textbooks for university-level courses in education (for example, Eggan and Kauchak, 1992) note that students are motivated to learn in classrooms in which order is maintained. Extreme differences on this classroom order variable have been noted between Japanese and American classrooms. Japanese classrooms are more orderly, even though the number of students per class is greater than in the average American classroom. The difference seems to be that Japanese teachers teach children how to pay attention and how to change activities with a minimum of upheaval while at the same time giving children responsibility for their own behaviour and that of their peers (Stevenson and Stigler, 1992). These things happen less often in American classrooms and may be just one reason why Asian students are said to be more motivated than their American counterparts. Obviously education at international and local levels will benefit from direct investigations of how this particular cultural difference in classrooms affects student motivation for learning. In general, we see this move toward motivation issues as an acceptance of Piaget's position that motivation and knowledge acquisition should be considered as opposite sides of the same coin.

Finally, it is important to remain aware that there is always a potential downside to learners' and teachers' constructivist tendencies, namely that they can lead us astray, to misunderstand-

ings and to misinterpretations. Of course this does not mean we are motivated to misinterpret or mislead. It can be a straightforward consequence of the way minds work. We can unknowingly misinterpret inputs (be they in school or out) on the basis of what we know already, just as we perceive illusions as a result of our normal perceptual processes. There cannot help but be times when we risk misinterpreting or even ignoring novel data, settings or events as a consequence of the normal mind's inclination to attend to and/or interpret what we encounter on the basis of what we know and believe to be true about the world and ourselves. And, of course, the longer we wait to introduce the novel, the better the chance that established knowledge systems will 'misinterpret' what is presented, often unwittingly. This argument adds weight to the widely held view that education at the primary- and secondary-school levels is all important.

Our goal, as educators, should be to understand as much as possible about the knowledge systems, and the cultural and sociolinguistic customs that children bring to specific learning situations. Such an understanding will allow us not only to use what children already know so as to introduce new information and encourage transfer, but also to anticipate domains (such as fractions) in which learning may be impeded by children's knowledge structures. Creating a better 'fit' between children and teachers can only serve to increase the motivation of both groups for their respective tasks. Key findings that bear on these goals are reviewed in the following sections.

The organization of knowledge

Discussions of the organization of knowledge usually refer to one of two questions: 'What is the inherent organization of knowledge?' or 'How should knowledge be organized in presentation?' In this section, we review findings relevant to both questions.

In the last two decades, research has consistently demonstrated that in every domain there are varying levels of understanding and that learning is a progression through those levels. More recently psychologists and educators have built upon this finding with investigations aimed at specifying the content of those levels in a variety of domains. This work is particularly important to educators interested in how the inherent organization of knowledge can provide guidance for the instructional organization of knowledge in order to assist the learner through progressive levels of understanding. Inputs need to be organized to represent vividly – and thereby cue in memory – the relevant facts and principles as well as the appropriate language and word meanings. We discuss various ways to do this, including how the clues and lessons gleaned from psychological research on the nature of concepts and classroom research, bear on methods of teaching mathematics and science. Our conclusion is that the previously prescribed sequence of presenting concrete inputs long before the abstract is not supported by recent research, which instead favours integrated presentations of concrete and abstract inputs for maximum conceptual understanding and transfer.

Levels of understanding

An important discovery about human thinking and learning is that we can represent the similarity between objects and events at many different levels, including ones that use deep principles about cause, objects, social goals and so on. It could hardly be otherwise given that we know that it takes about ten years of study and practice for one to become an expert at anything: several studies have documented this for fields as diverse as music, chess and diagnosing X-rays (Chi et al., 1988). Eventually experts come to organize their knowledge on the basis of principles of a domain. Although novices can solve a common set of problems, their knowledge is not organized this way. Chi et al.'s (1981) study of how novices and experts sort problems they both can solve illustrates the difference. Whereas novices group together problems with common props, for example a pulley or an inclined plane, experts group together problems that are related to a common law of physics, for example Newton's laws of motion. For a variety of domains and goals, attention to principles or structure usually results in more flexible knowledge for future learning and problem-solving. Brown et al. (1993) build this

assumption into their curriculum, which is designed to turn classrooms into 'communities of learning' (see also Bereiter and Scardamalia, 1989). An important part of their approach involves their commitment to the idea that the classroom is made up of many zones of proximal development (Vygotsky, 1978), which they operationalize as

> the distance between current levels of comprehension and levels that can be accomplished in collaboration with people or powerful artifacts. The zone of proximal development embodies a concept of readiness to learn that emphasizes upper levels of competence. Furthermore, these upper boundaries are seen, not as immutable, but rather as constantly changing with the learner's increasing independent competence at successive levels.

Brown et al. (1993, pp. 3–4) and Hatano and Inagaki (1986) similarly draw attention to the need to consider different levels of understanding in their discussions of contextual contributions to the development of routine *v.* adaptive expertise.

Organized inputs

Embedded in the above are some general guidelines for teaching. The first is that curricula should be designed to move students from where they are through *steps* of understanding. Otherwise, the intuitive theories of novices are likely to leave open too many opportunities to misinterpret the novel. Second, teachers should use multiple and different examples or experiments to teach a concept in order to capture effectively the complexity of a concept (Spiro et al., 1989) and to promote development of a schema (a flexible, generalized representation of the concept) which increases the likelihood that a person will appropriately use knowledge of that concept in future problem-solving situations. Multiple and different examples of inputs that exemplify a structure are known to foster learning and transfer (Hatano and Inagaki, 1987; Fried and Holyoak, 1984). Achievement-rich representation of concepts enhances transfer (Catrambone and Holyoak, 1989; Goswami and Brown, 1990). Verschaffel and De Corte (in press) found that children's errors in solving word problems were frequently due to an insufficient knowledge base. In an investigation of how to develop a richer knowledge base, Catrambone and Holyoak (1989) presented subjects with multiple analogous word problems and measured transfer to the solution of a superficially different word problem. They found that transfer was best when subjects received three rather than just two analogues, when the wording of the problems emphasized structural similarities between the problems and when subjects answered questions on the analogues which forced explicit comparisons between the examples and enhanced development of a problem schema. This type of instruction is also likely to support language learning. For example, vocabulary learning is enhanced if students have ample opportunity to relate new language inputs to the conceptual cores they represent (Beck and McKeown, 1989). Put differently, vocabulary instruction is best embedded in conversations about the concepts to which they refer. In the case of science, for example, this means talking about and doing science while learning content and vocabulary.

Structural accounts of learning also place emphasis on the ways in which complex knowledge bases map onto the inputs offered for learning. Learners have a better chance of assimilating the input if there is a good fit between what is to be learned and what is known. The fit can occur because of an overlap between the structure of what is known and what is given for learning. It can also occur because there is a match between the number of structural units a student can process and the number embodied in the data (Case, 1985; Halford, 1990). Without such fit there is a risk that the input will be ignored or mistakenly assimilated into the existing structure and knowledge base (Gelman, 1991).

Clues from the nature of concepts

The fundamental role of organization in cognitive performance has led researchers to ask how to characterize our knowledge. Research on the nature of concepts offers a potent clue as to where to look to modify traditional assumptions. The work bears particularly on the view that knowledge about concepts is always built up from the concrete or the perceptual. Although it is true that both adults and children often organize their con-

cepts on the basis of perceptual similarity, they also make use of deep principles. It is now recognized that were we to rely solely on perceptual similarities to make decisions about which items belong in which categories, we would make a lot of assignment errors (Medin, 1989). Yet we do not. Thus, although a red tomato and a red apple look alike, we have no difficulty saying they are not in the same category. In the same way, although a whale looks more like a fish than like a human being, we can classify it along with the human being as a 'mammal'. When we do this we use principled knowledge to override a classification based on perceptual similarity – even if we have trouble articulating the principle that led to correct categorization.

The implicit use of 'deep' relationships to categorize a variety of life forms is a universal achievement of the human mind (Atran, 1990). This does not rule out the role of culture, for the specific relationships that matter for a classification may depend on culture-specific accounts of the roles of certain objects (Murphy and Medin, 1985). For example, Bulmer (1967) reports that the Karam of New Guinea do not categorize a cassowary as a bird, because as a forest creature it has a special role in cultural ideas about the relationship between the forest and cultivation. The features of the cassowary that matter to the Karam are not those that matter for Western biological theories (Murphy and Medin, 1985), but both cultures share a dependence on deep, non-perceptual features of the cassowary for proper classification.

Just as we do not use simple perceptual similarity to categorize natural kinds, so we do not depend solely on surface appearances to classify artefacts. Young and old alike organize categories of artefacts on the basis of function and in turn use intended functions to determine how relevant a particular surface feature is to that function and thus how central it is to the concept. To illustrate, although an igloo, tent, adobe, house, cave, etc., vary widely in their shape and material, we classify them together because they all serve as dwellings and provide shelter. There are some similar perceptual characteristics – for example, an inside space – but these characteristics need not be the ones that are first apparent to the eye.

The deep principles used for categorization tasks need not be accessible to language. That is, we need not be able to state how our mind is making the categorization choices that it does. This kind of classification knowledge is often implicit. Similarly, implicit knowledge of causal principles enables the mind to take into account whether something moves on its own as well as some salient characteristics of the way it moves. Different peoples develop different culture-specific knowledge and theories about the causes and conditions of movement of the animate and inanimate items in their culture (Hatano and Inagaki, 1987). Still, these different models are built on a shared belief in the fundamental differences between the way animate and inanimate objects move. When we talked to a 5-year-old American child about a wooden bird hanging from the ceiling, he said: 'You know it's not a *real* bird. . .because it is too flat and too hard and is attached to the strings.' He tried in his own way to tell us that these are not characteristics of animate material, the kind of stuff that a *real* bird is made from.

In summary, representations of concepts are multilevelled. In many cases, people can rely more on deep, even implicit, principles than on perceptual similarities to classify objects and events.

Lessons from the study of mathematics learning

These new ways of thinking about the organization of knowledge have implications for educational programmes. Concept learning does not always proceed in one direction, from the perceptual (or concrete) to the abstract. In some cases, learning is maximized if the abstract is introduced alongside concrete examples. This is not to say that educators should move entirely to lessons that focus on abstract principles and knowledge. Rather, the idea is that a judicious mix of the concrete and the abstract will often enhance the development of understanding. Fortunately, we can share some examples of how this mix can be accomplished. Educators in Japan, the United States, Israel and Canada offer examples of successful integrations of concrete and abstract inputs in mathematics classes.

Visitors to mathematics classes for 6- and 7-year-olds in Japan and the United States will

notice a number of differences (Stevenson and Stigler, 1992). We focus on one particular kind: the different ways children are taught about number facts. In the United States, children might be introduced to these facts with the aid of various supporting materials. The idea is to introduce symbolic ideas with concrete, physical examples. The same materials might well be found in a Japanese classroom. However, they are used in a different way, for Japanese schools engage very young children in problem-solving and more abstract mathematical discussions about possible solutions from the start. For example, a child's erroneous solution to a problem might be written on the blackboard and used as a topic for class discussion. Were a teacher in the United States to do this, the children would surely be embarrassed, for attention would be drawn to their answers and to them as individuals. In Japan the error serves as an opportunity to engage the class as a group, a fact that helps explain why the child is not embarrassed. Similarly, correct answers serve as occasions to encourage children to think of different ways to state the mathematical problem, for example offering the idea that:

$$(3+4) = 1+1+1+1+1+1+1 = (2+2)+3 = 5+2\ldots$$

In addition to differences in how individual class sections are structured, Japanese teachers tend to provide more linkage between sessions than do their American counterparts. For example, homework assignments are discussed in terms of how they relate to what was learned the day before. Coherence in the lesson is derived from this discussion and from the successful integration of the concrete and abstract data about the relevant principles of mathematics. This is accomplished in large part by having children talk about mathematics in the language of mathematics while learning to use algorithms for doing particular problems.

Similar factors contribute to Lampert's (1986) successful efforts to bring her 10-year-old students to a principled understanding of multi-digit multiplication algorithms. In one series of lessons she first had fourth-grade students (average age = 8.5 years) learn to tell 'math' stories, for example, about the total number of children attending parties when 43 children go to 26 parties or 26 children go to 43 parties and so on. Next they were asked to make up stories for multiplication problems, for example:

Teacher: Can anyone give me a story that could go with this multiplication. . .12×4?
Jessica: There were 12 jars and each had 4 butterflies in it.
Teacher: And if I did this multiplication and found the answer, what would I know about the jars and the butterflies?
Jessica: You'd know that you had that many butterflies altogether.

The class then proceeds to represent Jessica's story in a concrete way. They also take groups apart and make new groups of different sizes, which demonstrates the numerical principles of decomposition and recomposition as well as the distributive law of multiplication. Eventually students get to the point where they can make up multiplication algorithms, a clear index of their principled understanding of multiplication. Note that the children themselves never talk about the distributive law or any other mathematical laws, but they do talk in ways that are consistent with the language and structure of mathematics (something that many researchers consider especially important these days) (Brown et al., 1989; Voigt, 1989).

Research from Israel converges on the idea that students in math classes benefit from abstract inputs that organize examples they are mastering. Nesher and Sukenik (1991) addressed the difficulty that high-school students have with formal representations of ratios and proportions. Their goal was to offer instruction to support acquisition of both implicit and explicit understanding. The latter is a necessary foundation if students are to learn more mathematics. The students started with explicit representations of all entities in the expression $a/b = c$. This was accomplished in a colour-mixing demonstration. Quantities of blue and yellow were mixed in water to generate green. Variations in the amounts of yellow yielded lighter and darker values of green. Students predicted how dark the green water would be as a result of mixing different quantities of yellow and blue. Since they received immediate feedback, they had an opportunity to compare their predic-

tions with the outcome and gain relevant information about ratios. This feedback enhanced learning to some extent, but the learning was most enhanced when these experiences were paired with the parallel relevant formal statements, quite likely because these offered a particularly apt structure within which to summarize the particulars of the experiment in a meaningful way.

A related example of the advantage of focusing instruction on the abstract, mathematical side of things prior to doing arithmetic problems comes from Griffin et al. (1992). They have designed a programme to encourage disadvantaged children to master conceptual understanding of the number line before they start arithmetic lessons. Doing this yields consistent positive effects across a varied set of cultural backgrounds, including Anglo-American, African-American, Latin American and recent Portuguese immigrants.

It is possible that the pairing of abstract mathematical talk with concrete examples emphasizes the fact that some natural language terms are false cognates in the language of mathematics. For example, although 'multiply' always means increase in a natural language, the same is not true in mathematics. Pupils are not warned of this difference, which surely contributes to their systematic errors on problems that require them to multiply two fractions together (Fischbein et al., 1985). A similar problem arises when 6- to 9-year-old children are asked to place either Arabic representations of whole numbers and fractions or N whole circles or parts of a circle on number lines. They often place 3/3 where 3 belongs on the number line, saying either that we said 'three' or that they counted three pieces. From the child's point of view such items are simply further counting opportunities. In the absence of being told to the contrary, it is hard to imagine how they could come to the right generalizations. In fact, Gelman (1991) reports that training designed to encourage children to relate the mathematical descriptions, relations and terms for fractions to different representations of fractions (including numerals, number lines, parts of circles and parts of squares) increases the likelihood that children will accept the idea that there are numbers between the whole numbers.

Lessons from the study of science learning

The literature on science learning adds weight to the theme that inputs should be organized in a way to support learning about relevant facts, the scientific principles that organize them and the related language. The reason, once again, is that people's misconceptions are tied to the way they reason and talk about scientific phenomena. For example, when people are asked to explain why objects stop moving, they typically talk about the loss of something akin to impetus inside the object. One subject told McCloskey and Kargon: 'At first, it [a toy car] still has the force from the push, so it's going fast; as the force decreases the car slows' (1988, p. 55).

As the authors point out, such talk fits well with pre-Newtonian conceptions of physics and the idea that forces are internal to a moving object. There is no reference to the Newtonian idea that the car will move at a constant velocity (for a given time) in the absence of the application of an external force. It is important to note that such answers came from students who studied a year of university-level physics and did well in their course! Furthermore, many of the same students tell interviewers that a ball will emerge from a circular tube and continue to go around in circles, as if the object's impetus will make it continue doing what it is doing already (McCloskey and Kargon, 1988). For these students, physics instruction was laid on top of a potent intuitive theory of motion. Typically, no effort is made to take intuitive theories into account, let alone confront them and organize instruction to create the conditions that might support conceptual change. Much like the case of mathematics instruction, supporting conceptual change means trying to increase understanding of core concepts and how principles relate these concepts to each other. It also means trying to move students to use the language of science in a way that is consistent with the concepts of science. And again, there are false cognates in the natural language. Whereas acceleration means 'speed up' in conversational English, it means 'change (positive or negative) in velocity or direction' in physics. Thus a decrease in speed involves negative acceleration.

The way in which language both impacts on and

reveals conceptual understanding is a recurring theme in educational research in mathematics and science. Our discussions point out that language has two roles in conceptual learning: learning the appropriate word meanings determines understanding of the accompanying principles, and achieving a level of understanding that allows articulation of concepts signifies a step beyond the implicit understandings which support judgement that cannot be expressed. Repeatedly historians of science note how the meaning of scientific terms is related to the concepts and the principles that organize these terms in a given domain of science (for example, Kitcher, 1982; Kuhn, 1970). Advances in our understanding of scientific concepts therefore move in concert with our acquisition of the language that refers to these. Learning about the language of science and the concepts therein can be thought of as learning about the two sides of a coin. Progress in learning about one bootstraps progress in learning about the other. The lesson here is that science instruction should involve students talking about and doing science at the same time as they are being introduced to the content of the discipline. A related lesson, one proposed by a number of researchers (Brown et al., 1993; Carey, 1988; Linn and Gelman, 1987), is that science instruction should focus on a limited number of key themes (for example, variability, interdependence and conservation) that organize a large range of phenomena and concepts.

Some cautionary notes

Finally, we offer three cautionary notes concerning the organization of knowledge. First, the emerging advice is *not* that schools should forget the concrete and focus on the abstract. Instead it is that schools should make efforts to teach content, language and domain-relevant principles together. The goal is to enhance the probability that learning about any of these can bootstrap learning about any of the others. The ultimate goal is understanding, but it is unlikely to be achieved if care is not taken to anchor the steps along the way.

Second, there is much current speculation about the need to develop expertise and encourage talk about the domain being taught. All seem to agree that the traditional recitation form of talk, where teachers ask questions in rapid succession and children are expected to give a 'right' answer, has failed to encourage learning how to think and talk about the domains in question (see Cazden, 1988, for a review). Similarly, many concur that a major part of learning involves acquiring coherent knowledge about a domain. Although many research-oriented educators encourage instruction designed to challenge students' naïve, intuitive concepts, encourage conversations about the content of the domain, ask teachers to take time to let their students fumble around for an answer and propose that students be encouraged to challenge and experiment, few offer guidelines for doing this. One approach is the use of thematic organization which allows students to explore a concept deeply to discover not only the relevant facts, but also the principles and language meanings tied up in that concept. However, as Goldenberg and Gallimore (1991) point out, it is hard to accomplish these goals in short teacher-training workshops and without finding ways to support teachers and schools in their efforts to change.

Third, theorists note that it takes time on task to achieve any understanding of new scientific and mathematical concepts. As Anderson (1992) concluded, the variable that consistently distinguishes groups of students who do and do not master these areas is the amount of time spent engaged in a task. There is simply no getting around the fact that elementary- and high-school students in Japan, for example, spend many more hours studying mathematics than do their counterparts in the United States.

In sum, advances in our understanding of the nature of concept learning offer clues for improving instruction, be it about history, reading, mathematics or science. In particular, it is no longer clear that instruction has to proceed from the concrete to the abstract when the goal is to ensure understanding of the abstract. Although the concrete sometimes can illustrate the abstract, it does not, on its own, offer unambiguous interpretations of the relationship between the principles of a domain (for example, mathematics and science) and their concrete applications. In order to prevent and rectify misconceptions, educators must provide guidance for students in how the concrete

is interpreted in language and symbols that are consistent with the target knowledge of the domain. We will return to the special role of language in the next section from a different but related perspective.

Putting learning and knowledge in context

Above we have resisted offering specific rules for taking laboratory findings into school systems all over the world. We now turn to our reasons for such reticence. Knowledge itself is dynamic and has multiple states, not just between learners of varying ability and experience levels, but within the same person at different times. Research in several areas of psychology has demonstrated that both the acquisition and use of knowledge is dependent on context. Converging evidence comes from cognitive psychology, ecological psychology and especially cross-cultural psychology. How the role of context should determine educational policies and methods is still being debated. In what follows, we discuss the pros and cons of one proposal for modelling educational practice on cultural traditions, the apprenticeship model.

Evidence from cognitive and developmental psychology

Bransford and Franks (1971) demonstrated that knowledge is not simply stored experience but is integrated with other knowledge. When given a recognition test for complex sentences which represented combinations of ideas presented earlier in independently presented, simple sentences, subjects falsely recognized the complex sentences, indicating that the related information in each of the simple sentences had been integrated rather that stored independently. Moreover, recalled knowledge is not retrieval of a static structure but a temporary construction based upon context, cues and goals at encoding and retrieval (Hyde and Jenkins, 1973). Several studies have demonstrated that recognition and recall changes when the context changes (Smith et al., 1970).

Developmental studies reveal a drastic change in performance with changes in task, environment and cues. For example, Shatz and Gelman (1973) demonstrated that 4-year-old children modify the complexity of their speech depending on whether they are talking to a child younger than them, to a peer or to an adult. Children of the same age, however, are 'egocentric' on Piaget's three-mountain task; that is, they say that someone on the other side of the mountain will see the same view they do. Egocentrism is not a characteristic of a child; it is a characteristic of thinking in specific task contexts. Research shows that children and adults keep separate their knowledge of everyday mathematics and school mathematics, be they in Brazil, Côte d'Ivoire, Liberia or the United States (Lave, 1977; Saxe and Gearhart, 1988; Saxe and Posner, 1982). It is also important to relate the study of cognition and learning to the ecological settings in which learning is embedded (see Bronfenbrenner, 1986; Shaw and Bransford, 1977, for reviews).

Evidence from cross-cultural psychology: the impact of culture, family and self

Perhaps the most powerful lessons about how context determines learning and cognition come from studies in cross-cultural psychology. These studies have demonstrated that culture determines abilities, curricula and classroom style, and family expectations and self-expectations of the role of schooling and personal achievement.

Cross-cultural studies of the problem-solving abilities of various people underscore how much our conception of intellectual abilities and our methods of researching them are influenced by our culture. Cole and his collaborators provide many compelling examples of how the conclusion that 'primitive tribal' people cannot engage in abstract thinking is false. The initial evidence that Liberians lack the ability to classify, measure and do logical problems failed to take into account potent confounds of the setting. For example, when the Kpelle are asked to measure with standardized units of measurement, they do not fare well. But any conclusion that they lack an understanding of measurement would be quite silly; they are skilled measurers. It is just that they use content-specific units, such as one for cloth, another for distance and so on. This is an es-

pecially poignant example, for in point of fact the tendency to wed the unit of measurement to what is being measured is very widespread. We use a troy ounce as opposed to a liquid ounce when measuring gold and other precious materials. Indeed, the adoption of common universal standards is very much a twentieth-century development.

Stigler et al. (1988) offer us a different perspective on the need to consider cultural differences in the study of abilities. It has been widely assumed that tests of digit span, the ability to repeat back as many digits as possible given a random string of them, is a relatively pure test of short-term memory. We no longer can assume this. It turns out that Chinese-speaking children have much longer digit spans than English-speaking children because the time it takes to say the count words is shorter in the Chinese language.

A comparison between American and Japanese children offers further lessons about the need to consider how cross-cultural factors determine curricula and classroom style. It is widely agreed that Japanese children score better on mathematics achievement tests – be these computational or conceptual in their focus (Stevenson and Stigler, 1992). Above we considered one reason for this, the different kinds of lessons that students are offered. Some have suggested that American schools would catch up if they simply imported Japanese-style lessons. This would probably be a mistake given that the way students are offered the opportunity to do and talk about mathematics in Japan fits well with certain aspects of Japanese culture. Similarly, many features of the American curriculum reflect deep cultural factors and beliefs that influence educators' choices. In the United States children are encouraged to develop as individuals. In Japan, the emphasis is on learning to share group values. Hence, the fact that schools in the United Staes favour efforts to individualize instruction and Japanese schools favour whole-class instruction are not theory-neutral facts. The tendency to give children in the United States individualized 'seat-work' in mathematics must be considered in the context of the constellation of cultural effects that influence choices about how lessons and schools are structured.

Clearly, any plans to change mathematics instruction cannot ignore the culture's values and prescriptions about the way children should be raised to share the values and goals of responsible members of their society (Hatano and Miyake, 1991). It is against this backdrop that we turn to consider how people's goals, values, implicit knowledge of their environment, social institutions and culture influence their interpretation of learning tasks and the role and functioning of schools.

Specific family expectations and values concerning the role of children in society as well as the role of schools in their lives contribute to the network of variables that distinguish the schooling experiences of children (Rogoff, 1990). Compelling examples of the network of these relationships are appearing in a variety of reports. For example, Japanese mothers are more inclined to attribute their children's school success to how hard they work in school, whereas American mothers will speak more of the role of native abilities. Vietnamese mothers prefer that the Australian schools their children attend focus on teaching school subjects; Australian mothers want schools to nurture their children's social needs.

Along with parent's expectations, different cultures can lead to differences in children's goals and self-expectations. Bandura (personal communication) found that single African-American and Latin American mothers finish their high-school studies at dramatically different rates, >80 per cent and <50 per cent, respectively. Interviews revealed that the African-American students' greater completion rates depended on their sense of place in their community. They said they knew that they could not count on others taking care of them and their children in the future. Therefore, they had to be sure to obtain the education needed for a good job. They also noted that their community encourages the use of grandmothers for child care. Latino students emphasized different issues, including the tendency of the family to stick together and take care of all of its children as well as the embarrassment of having an unwed mother in the family. These young women were encouraged to quit school and stay at home.

In many places in the world, girls and boys face different expectations about whether they will go to school, what they should learn and how long they should stay in school, and these different

expectations for girls and boys can influence factors such as attendance records. Families' ideas about the developmental agenda for when and what children should do in the way of household chores varies as a function of sex (Goodnow and Collins, 1990). We know of 12-year-old Puerto Rican girls living in Philadelphia (Pennsylvania) who stay out of school whenever there is a household need that requires an English speaker, for example arranging for delivery of a washing machine or being available when a service person comes to the home. Their brothers do not provide this service for the family. These are not the kind of behaviours that are typical of 'truant' children. Instead they reflect the ways that families' expectations of their children may not fit with those of the schools.

Variations in cultures are also reflected in variations in sociolinguistic rules. The ways in which languages map rules of discourse vary both as a function of the language and of the community that speaks the language. Politeness markers are typically indirect in English; there is no parallel to the French *tu/vous* distinction. Not surprisingly, then, the differences between direct and indirect requests in French do not map one for one onto the differences in English (Bernicot and Makrokhian, 1989). Given that knowledge of sociolinguistic rules influences children's interpretations of both the agenda that schools set for them and classroom discourse, failure to appreciate such influences is likely to have serious consequences.

The effect of culture is not a uniform blanket across all the individuals in a group. Rather than influencing all members in the same manner, culture can have the effect of creating niches for individuals and setting certain expectations for them that can powerfully influence performance. Dweck and Bempechat (1983) draw attention to the difference between failure-oriented and mastery-oriented children. Mastery-oriented children treat obstacles as challenges, reasons to modify their strategies, reasons to try again, etc., and thus fit our model of the self-motivated learner. The same cannot be said for failure-oriented children.

Those who come to think of themselves as 'not good at school things', 'too dumb to learn to read and do math', etc., come to question their personal efficacy in school settings (Bandura, 1980). They invest a great deal of energy in minimizing demonstrations of failure on their part. They devalue school tasks, count on teachers knowing not to embarrass them by calling on them (Cole and Traupman, 1981) and expend a great deal of effort looking as though they are doing something when they really are not. Their failure-orientation influences their perception of their performance. If they get something right, it is due to luck; if they get something wrong, it's just more proof that they are incompetent. We know that children's cultural niche interacts with their sense of their self-efficacy, but we have far to go to understand the reasons and consequences of this relationship (Heckhausen, 1982; Sinha, 1982; Steele, 1992).

Of course, what families might want to do for their children interacts with issues of politics and economics. Desires to visit children's teachers and help with homework do not matter if work and school schedules conflict, or if parents are embarrassed to admit they know less than their child because they were too poor to go to school. Prescriptions to read books or use hands-on science materials are hard to follow if there are no funds to buy them or if there is no transportation or food. And, subgroups who feel stigmatized or devalued may assume they are not competent to achieve high levels of success. Steele's (1992) account of why 70 per cent of all African-Americans at four-year colleges drop out before they finish their degrees is a particularly disturbing example of the potency of these self-attributions.

The foregoing illustrates what is surely a universal truth. Successful transfer of research about school learning depends on our ability to transfer our findings in ways that fit, as well as possible, the implicit assumptions children, their families and their communities have about schooling and the topics that are taught. Unfortunately, there are no recipes for doing this. It is therefore crucial that attention be given to the way different influences on performance are likely to play out in different cultural settings. So, too, is it crucial to keep in mind different models of teaching and how they might be adapted to teach the range of literacy skills needed for successful negotiation of the challenges one faces as an adult member of a com-

munity. We turn to consider a class of models that is attracting a lot of research attention in educational settings these days – the apprenticeship model.

Apprenticeships as models of school learning

Some have proposed that the interconnections between knowledge and context are so extensive that we err in trying to teach knowledge and general decontextualized learning skills (for example, Brown et al., 1989; Lave and Wenger, 1991). This trend is consistent with scholars like Bordieu (1972), who have focused attention on learning that involves participating in the practices of one's community. Through the 1980s there has been a growing commitment to the idea that we should establish situated learning environments for transmitting the kind of knowledge schools were set up to teach. More and more attention has been paid to the possibility of using apprenticeship models to this end.

The appeals of the apprenticeship model are many. When they work, apprenticeships provide on-the-job training, limit the amount of negative feedback individuals encounter, offer a community of models for learners to watch and be watched and helped by, generate some income and constitute a social network. As Lave and Wenger (1991) point out, there are many cases in which the apprenticeship model does work, the case of how Liberians become tailors being an especially compelling one. Their characterization of the reasons for success serve as the background for Collins et al.'s (1989) proposal that schools become sites where students serve as cognitive apprentices. The goal is to lead students to share in the practices of those who work at acquiring and using knowledge of a particular kind. They use examples to illustrate what one might expect of a cognitive apprentice.

One example of how a cognitive apprenticeship system could work is Schoenfeld's (1987) method of teaching college-level mathematics. He encourages students to bring problems to class to give him, the teacher, to solve. By doing so, he explicitly shows that doing mathematics is a complex business. It involves using heuristics, generating hypotheses, making guesses, reaching dead-ends and so on. Schoenfeld also works through problems with the class, an approach that leads to talk about and comparisons of different lines of attack, why a dead-end is a dead-end, why two seemingly different solutions both work, etc. Collins et al. (1989) argue that such discussions serve as the intellectual food needed for reaching explicit understanding, seeing the merits of strategies and being able to take on novel problems. In short, they propose that 'cognitive apprenticeships' mediate the development of the kinds of metacognitive skills students can use to approach related problems. We will return to a discussion of these skills and why, for us, this kind of teaching is more appropriately called a cognitive mentorship. We note that there is much in their proposal that fits with the kinds of themes developed above. Similarly, the notion Collins et al., (1989) call 'cognitive apprenticeship' overlaps a great deal with other model programmes that attempt to embed ways for students to talk about a domain in relevant ways and under domain-relevant conditions. But there are some notable differences.

Brown and his colleagues (Brown et al., 1993) consider it romantic to talk about inducting elementary and high school students into the cultures of historians, mathematicians, linguists or whatever. There is the very practical problem that practitioners of these cultures seldom teach school at these levels, a problem that would surely be magnified in places where there are almost no members of these cultures. We add that when such a model is used, the learners are usually graduate students who have been selected by the masters as especially likely candidates for success. That is, they already know enough and/or are talented enough to merit the master's involvement in their apprenticeship. It is also important to recognize that there are likely to be individual differences in the apprentice level that individuals will rise to. In Senegal, all who are in training to become tailors learn how to do buttons and hems; only some move on to master especially intricate embroidery (Lucy Colvin Phillips, personal communication, 1992). Brown and his colleagues (Brown et al., 1993) continue that schools are cultural institutions expected not only to prepare citizens to take their place in the job force, but also to

help them learn how to solve problems and to master the new technologies and demands they are sure to confront in the future.

Despite the above cautionary notes, there are reasons to want to understand how and when apprenticeships can serve as teaching or learning models, for they are used successfully to prepare people for a wide range of jobs (mechanic, academic researcher, musician, hotel clerk, travel guide in the Okavanga Delta, plumber, etc.). Apprenticeships have been studied as models of cognitive change by several researchers. Lave and Wenger characterize an apprenticeship as a 'legitimate peripheral participation', wherein the learning involves 'partial participation in segments of work that increase in complexity and scope' (1991, p. 80). Discussions of apprenticeships share a commitment to the central concepts of: everyday or authentic work activities; the presence of a master and a learner (or expert and novice); mutual participation in the work activities; the gradually increased participation by the learner/novice; reliance on implicit learning mechanisms like imitation and modelling; and a de-emphasis of explicit instruction. These characteristics of apprenticeship are related to the way roles, interactions and tasks are structured.

By definition, an apprenticeship includes at least one person who has mastered a skill and another person who desires to acquire that skill. They might be called master and apprentice, expert and novice, model and learner, but in all cases both are participants in the task. We believe that the embedding of these roles in a successful apprenticeship carries with it an assumption of eventual parity. Despite the differences in knowledge to start, a successful apprenticeship is meant to generate a new master. In this sense, then, the very concept of apprenticeship implies a future in which the learner shares the master's status. The concept that an apprentice is a future master grants legitimacy to the apprentice and creates maximum similarity between the roles (emphasizing only the current knowledge differences), and between learning and future performance. This characterization contrasts with the teacher–pupil relation. There is no presumption in school systems that all pupils will one day become teachers or assume roles of equal stature.

Apprentices interact closely with their masters and others in the same trade. This supports learning by imitation and is consistent with the fact that apprentices receive less explicit feedback and instruction than do students in traditional schooling environments. Lave (1977) observed that Liberian tailors rarely commented to their apprentices on their attempts to construct garments. Instead feedback came via attempts to sell the garments: the apprentice would know his success by the price of the garment. Similarly, Rogoff's (1990) notion of guided participation argues that a parent provides feedback on a child's performance by changing a task more than by commenting on it. As the child's role becomes more complex, the changing task not only allows new learning to begin but also provides implicit feedback about the success of the previous stage.

One reason feedback might be built into the apprenticeship setting is that successful models are omnipresent; that is, all members of a work group, including both masters and apprentices, serve as models by virtue of the fact that all are participating in the related work tasks. This is related to Lave and Wenger's (1991) conclusion that access, both physical and psychological, is an important contributor to successful apprenticeships. They report that apprentice butchers whose view of expert butchering activity was obstructed by the environmental layout failed to learn the necessary skills.

Access may vary with the medium and the task. Lave and Wenger (1991) acknowledge that not all expert models need be humans – one source of access to expert models is technology, especially in the form of computer models which can perform expert tasks. Access is surely likely to vary as a function of the cultural dimensions that contribute to shared status. Apprenticeship systems that require people to be slaves or servants are hardly systems for motivating individuals to assume the same level of skill as the master. For this reason, we might also imagine that the language used to talk about the different roles will matter. It is a different matter to be able to say 'one is in training to be a master' as opposed to 'one is a servant to a master'. Indeed, the word *master* takes on different meanings in these different linguistic contexts.

Research on the nature of implicit learning mechanisms helps explain some of the characteristics of apprenticeship learning. According to Reber (1989), implicit learning processes rely on 'lower level' cognitive mechanisms such as pattern perception. Implicit learning is known to result from repeated experience with stimuli, without awareness of the learning or an ability to talk about it. Typically, what is learned is about frequency and covariations between features, relations and other observable aspects of the stimuli. Learning is slow and depends on extended experience; it results in good, but not perfect, performance and extremely limited success on related transfer tests (see Holyoak and Spellman, 1993, for a recent review of relevant experiments).

The notion of access as defined by Lave and Wenger (1991) and the reliance on implicit learning provide clues not only about reasons for the success of apprenticeship in its many manifestations outside the schools but also about the limitations of using apprenticeship methods to meet the goals of formal education. Lave and Wenger's ideas of access should be kept separate from those advanced by theorists who use the term in theoretical discussions of ways to develop internal representations of knowledge and enhance flexible thinking. For Lave and Wenger, access refers to the availability and visibility of an external model of task performance. For others, access is related to understanding. If knowledge acquisition has proceeded to a point where one has a principle of understanding, then transfer is possible. This is because the principles can be adapted to a wide variety of settings, as long as they all offer relevant structured inputs. Brown and Campione (1981) argue that such access is possible only when a learner has reached a sufficient level of understanding to allow representation at an explicit, verbalizable level. Hatano and Inagaki's (1986) discussion of the varying levels of understanding revealed in routine expertise (the accurate performance of a task with little variance) and flexible expertise (the adaptive performance of a procedure under varied conditions and contexts) seems to correspond to the different notions of access discussed by Lave and Wenger (1991) and Brown and Campione (1981). When reliable, accurate execution of a task is the goal, the key to learning may indeed be external access to a performance model. But when flexible thinking is the goal of the learning situation, internal access is needed, and how that access is achieved may be remarkably different. This distinction is crucial because the ultimate goal of formal education is not routine performance but flexible thinking.

Similarly, implicit mechanisms create a means for learning fundamental things about how to do something. But the goals of formal education are more extensive. We aim to enable a student not only to do some task, but to alter it in order to do it flexibly, and to talk about it, in order to transmit it to others and to allow self-access as well as access for others to measure understanding and alter procedures as well. As we discussed earlier in the context of mathematics and science learning, talking about concepts is an essential part of the educational process, a part that is not possible without explicit – in addition to implicit – representation of those concepts. Articulation, not just observation and participation, is an irreplaceable element of formal education.

Lave and Wenger's (1991) criticisms of explicit learning conditions should be considered in view of these ideas about access and the nature of implicit learning. Educators, including those who advocate what has been called cognitive apprenticeship, continue to focus on teaching mindful strategies for problem-solving, decision-making and managing mental resources in the classroom because their goal is most frequently not routine expertise but flexible expertise. This is not to say that they have not been influenced by arguments about context effects. Indeed, it is common to hold the view that the most likely way to encourage general learning and thinking skills is to embed training in lessons designed to develop rich and organized knowledge bases (for example, Brown et al., 1993; De Corte, 1990). But it is clear that explicit instruction has not been and should not be abandoned. This is clearly seen in models of cognitive apprenticeship discussed earlier (Collins et al., 1989; Schoenfeld, 1987). Those models focus not just on providing external models of task performance, but also on the use of articulation and interaction (mostly verbal) as a method of developing and monitoring explicit understanding of a domain. Traditional apprenticeships do not

engage in such explicit instruction, according to Lave and Wenger. To adapt the idea of modelling task performance for the classroom it is necessary to accommodate the goals of formal education, which include flexible performance and articulation of procedures and goals. For this reason, we recommend that a more appropriate label for these models is *cognitive mentorship*. A mentor, unlike the master of an apprentice, does not just create an opportunity for a student to learn – he or she instructs the student in what, how and why to learn as well. This latter type of instruction is often the hallmark of excellent educators and is the key to producing a motivated, skilful and eventually self-guided learner, which is the goal of many education systems.

One valuable lesson for educators in the comparison of formal education with studies on apprenticeship learning is that there is more than one way to learn. In her initial study of how Mayan mothers apprentice their daughters to the skill of weaving, Greenfield (1984) highlighted how the mothers stuck close to their daughters. Few errors were made because the mothers moved their charges through a series of steps as they were ready for them. Increases in the number of jobs available to adults can lead to changes in their roles as mentors, as illustrated by the work that Greenfield is doing in her follow-up of the next generation of families. She finds that many girls no longer learn to weave at their mothers' sides. The reason is straightforward: their mothers now have additional tasks. Some are working on pieces specially designed for tourists to buy. Some young girls are learning by watching their sisters and trying to weave on their own. As a result, they are making errors that their mother might take out at night but not criticize them for.

There is surely more than one learning path to knowledge. It is neither necessary nor wise to assume that there will be one best way to transmit to our children the knowledge they need. Especially where the increasing complexity of life places more and more demands on adults to cope with and excel in a variety of areas, we should not be surprised if there is a continuing division of labour regarding the education of our young. There is evidence that this has already started to happen. Gelman et al. (1991) report that parents of young children (7 years old or less) vary their tendencies to use exhibits as teaching opportunities. They offer their children extensive guidance and information at exhibits about daily life, for example those about transportation, food shopping and visits to the doctor. In contrast, parents typically allow their children to visit by themselves the exhibits that feature numbers and science. The effects of exhibit type on parental involvement were salient enough to warrant a collaboration between Gelman et al. (1991) and a museum to develop alternative techniques for assuring that children interpret and use the mathematics and science exhibits as intended. This led to an exhibit with an interactive video that started when sensors picked up the presence of someone at the exhibit. Children now responded to suggestions to experiment (and parents started to join in when they saw what their charges were doing).

Conclusions

The original notions of learning as a process of building associations have both multiplied and mutated. While some of these principles continue to be used in connectionist models of learning and in theories of implicit learning, it is clear that there are other paths of learning which go beyond these conceptions. We have seen that the learner is not a passive recipient, but an active constructor of knowledge who benefits from inputs structured around deep principles which advance the learner from his or her current level of understanding to deeper and more flexible levels of understanding. While understanding continues to be a somewhat mysterious notion, psychologists and educators agree that indicators of understanding include the ability to solve a variety of problems in a domain flexibly and the ability to talk in appropriate language about the principles which shape that domain. The role that contextual factors such as language, cultural models, and family and self-expectations play in learning has influenced new models of how these abilities are acquired. These models range from those that emphasize variation in context, methods and presentation format of problems in order to empha-

size the underlying principles of a domain, rather than surface similarities, to those that advocate importing models of instruction traditionally used outside of formal education as a more culturally relevant method of education. The debate about which methods are most suitable centres around the differences between instruction and education, what kinds of inputs and access are necessary, and the merits of both implicit and explicit learning. Recent research suggests that there are multiple ways of learning and that each has a role in education. Trial and error experimentation, imitation of models and more systematic explorations leading to statable principles all contribute to the development of a knowledgeable, flexible learner.

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The mathematics achievement of American children lags behind that of most students from other developed countries. While some view curriculum reform, better teacher training and smaller class sizes as ways to improve achievement, psychologists who study learning believe that improvement will come only when students spend more time effectively engaged in the learning task. One way to engage learners is to integrate computer-based tutors into the classroom. One such tutoring system is called *model-tracing tutoring*. The system is so called because the computer develops a model of the correct way to solve problems (for example, in geometry) and uses this both to interpret a student's problem-solving behaviour and to provide feedback about that behaviour. By choosing certain paths to a solution, the students guide their own learning as much as they are guided by the tutor's feedback. By proceeding step-by-step through a problem, the solution is reached by the student and the tutor rather than simply being given by a teacher. Research shows that computer tutoring systems increased geometry achievement by an average of one letter grade and accelerated learning as well. Providing such benefits to each student in the American education system will depend on programming hundreds of hours of instruction into tutoring packages. Changes in ideas about school organization, such as the role of the teacher as facilitator rather than instructor, and a de-emphasis on obvious tracking of students by ability level, are also crucial to the success of computer-based tutoring.

Atran, S. 1990. *Cognitive Foundations of Natural History*. Cambridge, Cambridge University Press.

Baillargeon, R. S.; Spelke, E. S.; Wasserman, S. 1986. Object Permanence in the Five Month Old Infant. *Cognition*, Vol. 20, pp. 191–208.

The experiment consisted of two parts, a habituation phase and a post-habituation phase. During the first phase, 5-month-old infants were first shown a screen as it rotated through an 180° arc, the trajectory of which moves towards and away from them. When their interest in looking at the rotating screen declined by 50 per cent, that is, when they habituated to the particular display, they were moved onto the second phase. To start this phase, the screen was stopped in an upright position and they were shown a yellow cube, placed to one side of the screen. Once the infant looked at the object, the experimenter moved it out of sight behind the screen. This set the stage for the post-habituation phase of the experiment. Once again the screen rotated toward and away from the infant. Given the physics of the situation, the screen should have stopped at about the 110° position of its rotation. But if, as it once did, it continued through an 180° arc (thanks to the use of trick mirrors), adults 'saw' an impossible event, one where the block behind the screen is repeatedly crushed and uncrushed as the screen moves through the 180° arc. Adults believe that one object cannot pass through another – save in the world of imaginary ghosts. If infants share our knowledge then they should be surprised by the impossible event. If, as Piaget concluded, infants this young believe that objects exist only as long as they can see them, then the impossible event should not bother them. This means that they should continue to be bored by the screen that passes through a full 180° arc and treat the 110° arc rotation as more novel. Infants looked more at the impossible event, showing that they must have changed their interpretation of the 180° arc event. If we consider just the surface information available to them, there is no difference between the impossible and habituated events. Both involve the screen rotating through a 180° arc. To treat these as different requires a conceptual interpretation of the conditions, that is, the fact that there is a solid block behind the screen.

Bandura, A. 1980. Self-referent Thought: The Development of Self-efficacy. In: J. H. Flavell and L. D. Ross (eds.), *Development of Social Cognition*. Hillsdale, N.J., Lawrence Erlbaum Associates.

Bassok, M.; Holyoak, K. J. 1990. Pragmatic Knowledge and Conceptual Structure: Determinants of Transfer between Quantitative Domains. (Paper presented at the annual meeting of the American Education Research Association, Boston. Mimeo.)

Bassok and Holyoak discuss the reasons behind the finding that students' understanding of algebra solutions transfers readily to their attempts to solve physics problems, but transfer in the other direction (from physics to algebra) is highly problematic. The authors draw a distinction between the domains of algebra and physics based on the degree to which information taught within each domain is considered

context-bound. Students of physics are generally taught to solve a distinctive set of problems with a specific set of procedures. Algebra teaching instead tends to be more abstract and algebraic procedures are applied to a wide range of problems with varying content. Differences in the degree to which these domains are taught in a content-specific versus content-free manner are considered by Bassok and Holyoak to be the reason behind the asymmetrical transfer found between them. The content cues of physics problems (including the types of units) are assumed to limit the applicability of these problems to the solution of algebra problems. Transfer from algebra to physics is obtained more easily, presumably because of its content-free nature. The findings of Bassok and Holyoak suggest that the context of learning affects the learner's understanding of which features of problems in both the original and transfer domains are important to attend to.

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Brown, A. L. 1990. Domain-specific Principles Affect Learning and Transfer in Children. *Cognitive Science*, Vol. 14, pp. 107–33.

Brown, A. L.; Ash, D.; Rutherford, M.; Nakagawa, K.; Gordon, A.; Campione, J. C. 1993. Distributed Expertise in the Classroom. In: G. Salomon (ed.), *Distributed Cognition*. New York, Cambridge University Press.

Changing the ethos of the classroom has been the focus of several educational reformers. Brown et al. provide an example of an ambitious reconstruction of fifth- to seventh-grade biology and environmental science classrooms. Such projects appear to have great potential for improving not only the design of the education process, but also the students' attitudes towards acquiring knowledge.

Brown et al. describe their classrooms as 'communities of learners'. In these communities, students are inducted into the practices and discourse of the scientist. Their aim is not to reproduce the cultures of mathematicians and scientists in the classroom but to provide an authentic environment in which students may 'adopt the ways of knowing, discourse patterns, and belief systems of scholars'. In effect, their goal is to assist the students in 'learning to learn'. Students acquire research, evaluation and communication skills. Brown et al. focus on 'depth of understanding and explanatory coherence', rather than 'breadth of coverage and retention'.

As participants in a community of learners, students specialize (or become 'authorities') in aspects of the class research topics that interest them most. The result is that students acquire distributed expertise. The students then collaborate and co-operate so that a shared knowledge base is developed. Brown et al. also refer to their classrooms as 'communities of discourse'. As such, students engage in constructive discussions of their findings. They jointly negotiate meanings and serve as critics of each others' work. Discussion takes place in an atmosphere of mutual respect. Students' questions are taken seriously and the students learn to listen to one another.

The goal of Brown et al. is for students to become 'intelligent novices'. As participants in communities of learning and discourse, it is hoped that students will develop the skills that will allow them to gain knowledge in any area they desire to learn about.

Brown, A. L.; Campione, J. C. 1981. Inducing Flexible Thinking: A Problem of Access. In: M. Friedman, J. P. Das and N. O'Connor (eds.), *Intelligence and Learning*, pp. 515–30. New York, Plenum Press.

——. 1990. Communities of Learning and Thinking, or A Context by Any Other Name. In: D. Kuhn (ed.), Developmental Perspectives on Teaching and Learning Thinking Skills (Special Issue). *Contributions to Human Development*, Vol. 21, pp. 108–26.

Brown, J. S.; Collins, A.; Duguid, P. 1989. Situated Cognition and the Culture of Learning. *Educational Researcher*, Vol. 18, No. 1.

Many present teaching methods assume that knowledge comprises formal concepts which are theoretically independent of the situations in which they are learned and used. Students may learn many mathematical formulae and develop facility in demonstrating that knowledge. They may, however, have great difficulty in applying those formulae to the resolution of real-world problems. It is argued here that knowledge is fundamentally *situated*, that knowledge is not separable from the activity and the culture in which it is developed. Learning, then, is a process of enculturation; it requires exposure to concepts through authentic problem-solving activities.

The notion of situated cognition calls for more attention to learning activities which are context-embedded. Such *cognitive apprenticeship* methods involve students in activities and social interactions that are similar to craft apprenticeships. This approach is examined in two illustrative examples of mathematics instruction.

Bulmer, R. 1967. Why is the Cassowary Not a Bird? A Problem of Zoological Taxonomy among the Karam of New Guinea Highlands. *Man*, Vol. 2, pp. 5–25.

Catrambone, R.; Holyoak, K. J. 1989. Overcoming Contextual Limitations on Problem-solving Transfer.

Journal of Experimental Psychology: Learning, Memory, and Cognition, Vol. 15, pp. 1147–56.

Carey, S. 1985. *Conceptual Change in Childhood.* Cambridge, Mass., MIT Press/Bradford Books.

——. 1986. The Acquisition of Scientific Knowledge: The Problem of Reorganization. In: S. Strauss (ed.), *Ontogeny, Phylogeny, and the History of Science.* Norwood, N.J., Ablex Publishing Corp.

——. 1988. Why Jane and Johnny Aren't Learning Science Yet. (Paper presented at a Science and Public Policy Seminar sponsored by the Federation of Behavioral, Psychological, and Cognitive Sciences, Washington, D.C. Mimeo.)

Carey, S.; Gelman, R. (eds.). 1991. *The Epigenesis of Mind: Essays on Biology and Cognition.* Hillsdale, N.J., Lawrence Erlbaum Associates.

Carpenter, T. N.; Fennema, E. 1989. Building on the Knowledge of Students and Teachers. (Paper presented at the Thirteenth International Meeting of the Psychology of Education Association, Paris. Mimeo.)

Case, R. 1985. *Intellectual Development: A Systematic Reinterpretation.* New York, Academic Press.

Cazden, C. 1988. *Classroom Discourse: The Language of Teaching and Learning.* Portsmouth, N.H., Heinemann.

Recitation is the most common method of instruction in American classrooms. This form of classroom discourse is problematic for children who are not accustomed to its use. The forms of discourse that are used in classroom settings are to some extent new to all children. Some children, however, are placed at a greater disadvantage than others because there are greater cultural and linguistic differences between their home and school environments.

Cazden discusses this issue and offers some remedies. She describes two situations in which ethnographers studied the problems faced by children culturally unprepared for the typical communicative context encountered in school. In both of these cases, the ethnographers not only documented differences between the cultures of the communities and the school, but also collaborated with teachers to design more positive learning environments, including new participation structures that provide a better fit with students' communication patterns at home. Interventions such as these appear to be quite successful in combating the problem of cultural discontinuity between home and school.

Cazden also discusses three specific methods used by teachers to assist their students in responding to questions. The first is termed 'preformulating'. Teachers use this method before posing a question to help students determine the relevant area of expertise or the boundaries of the content matter under consideration. Cazden calls her second method 'reformulating'. This method includes teachers' attempts to make a question more specific, particularly after receiving an incorrect response. The cognitive demands placed on the children are lessened as open-ended questions are gradually reduced to questions requiring children to choose one of a few alternatives or simply to answer 'yes' or 'no'. The third method described by Cazden is termed 'formulating' or 'reconceptualizing'. This final approach refers to teachers providing summaries of or expansions on children's responses that serve to place the students' answers in a wider context or to highlight connections that may be drawn to material that has already been discussed.

Chi, M. T. H.; Ceci, S. 1987. Content Knowledge: Its Representation and Restructuring in Memory Development. In: H. Reese (ed.), *Advances in Development and Behavior.* Orlando, Fla., Academic Press.

Chi, M. T. H.; Feltovich, P. J.; Glaser, R. 1981. Categorization and Representation of Physics Problems by Experts and Novices. *Cognitive Science*, Vol. 5, pp. 121–52.

The authors contrast the methods by which experts and novices categorize and solve textbook problems in the domain of physics. The initial task was to classify a series of problems using whatever criteria they chose. Experts were found to sort problems based on the physics principles (energy laws, Newton's second law, etc.) underlying the problems. In contrast, novices sorted the problems on the basis of their visual features, including the type of apparatus involved (levers, inclined planes, etc.). The novices' solutions were much more context-bound than those of the experts. The ways in which novices think about a problem are shaped by the problem's presentation. Experts think about the problems more abstractly and use their previous knowledge to reshape the problems so that they are more readily solved.

Novices and experts also attempt to solve problems in different ways. Novices start with the variables that are given in a problem presentation and attempt to identify the formulae that include them. They continue their solution attempts by working forward from their initial equations, using algebraic manipulations eventually to determine the values of the unknown variables. The experts instead first reinterpret the problems and identify the key relationships involved in the problem description. Experts write fewer equations than novices because they have virtually solved the problems by the time they write their equations. They already know what they are solving for and move quickly toward their goal. The experts' methods thus contrast sharply with the trial-and-error attempts of the novices.

Both the sorting and problem-solving methods of the experts and novices indicate that novices' solutions are tied much more closely to the surface features of the problems than those of the experts. The experts' greater knowledge base allows them to go beyond the surface features of problems; their solutions instead rely on the more abstract principles they are based on.

Chi, M. T. H.; Glaser, R.; Farr, M. J. 1988. *The Nature of Expertise.* Hillsdale, N.J., Lawrence Erlbaum Associates.

Chomsky, N. 1965. *Aspects of the Theory of Syntax.* Cambridge, Mass., MIT Press.

Clark, A. 1991. In Defense of Explicit Rules. In: W. Ramsey, S. P. Stich and D. E. Rumelhart (eds.),

Philosophy and Connectionist Theory, pp. 115–28. Hillsdale, N.J., Lawrence Erlbaum Associates.

Cole, M. S.; Traupman, K. 1981. Comparative Cognitive Research: Learning from a Learning Disabled Child. *Minnesota Symposium of Child Development.* Hillsdale, N.J., Laurence Erlbaum Associates.

Collins, A.; Brown, J. S.; Newman, S. E. 1989. Cognitive Apprenticeship: Teaching the Craft of Reading, Writing, and Mathematics. In: L. B. Resnick (ed.), *Knowing, Learning, and Instruction.* Hillsdale, N.J., Lawrence Erlbaum Associates.

De Corte, E. 1990. Acquiring and Teaching Cognitive Skills: A State-of-the-Art of Theory and Research. In: P. J. D. Drenth, J. A. Sergeant and R. J. Takens (eds.), *European Perspectives in Psychology*, Vol. 1. London, John Wiley & Sons.

De Corte, E.; Verschaffel, L.; Schrooten, H. 1989. *Cognitive Effects of Learning to Program in Logo: A One-year Study with Sixth Graders.*

De Corte et al. investigated how effective an environment the Logo computer language is for the acquisition and transfer of problem-solving skills. The particular skills in question were two metacognitive skills (planning and debugging) and two heuristics (problem decomposition and construction of an external problem representation). The authors proposed that three prerequisites must be satisfied if transfer is to occur. The first is that children receive ample domain-specific knowledge. (Children learning basic Logo concepts met this condition.) Second, the mastery of strategic skills (that is, the heuristics and metacognitive skills necessary for programming) is required. Finally, one must be successful in transferring skills learned in the Logo domain to another domain. De Corte et al. predicted that if the first two conditions were satisfied, then transfer would occur. However, satisfaction of the third condition would lead to better transfer.

The study was conducted in a pre-test/post-test manner, with three groups. The two experimental groups (E1 and E2) were identical except for exposure in a transfer domain. The Logo language was taught to both groups, but only E2 was additionally given explicit instruction in another domain (mathematical word problems) in order to enhance transfer. The control group was not taught in either domain.

Results indicated that children from both experimental groups had mastered three of the skills learned in Logo (debugging, planning, and construction of external representations). However, explicit transfer instruction did not enhance E2 children's ability. The authors claim that this result is inconclusive and provide reasons for why they did not get the desired result.

De Corte et al. conclude with a discussion of future Logo research topics, particularly regarding its 'cognitive power' and learning environments in which its implementation will be effective.

Dillon, J. T. 1985. Using Questions to Foil Discussion. *Teaching and Teacher Education*, Vol. 1, pp. 109–21.

In this paper, Dillon claims that when teachers use questions to stimulate discussion in the classroom, they often succeed only in reducing classroom participation. Dillon used a case-analysis method to study the effects of questions and their alternatives in five secondary-school classrooms. He found that students' contributions to class discussions became shorter and shorter as the instructor introduced more questions, regardless of the cognitive level of the questions. When the instructor instead used declarative statements to summarize and recast students' comments, shared his own opinion, invited the students to raise questions, or just remained silent, student talk not only increased, but became richer in content. Students became more personally involved, more students participated and more complex thoughts were expressed.

Dweck, C. S.; Bempechat, J. 1983. Children's Theories of Intelligence: Consequences for Learning. In: S. G. Paris, G. M. Olson and H. W. Stevenson (eds.), *Learning and Motivation in the Classroom.* Hillsdale, N.J., Lawrence Erlbaum Associates.

d'Ydewalle, G. 1987. Is It Still Worthwhile to Investigate the Impact of Motivation on Learning? In: E. De Corte, H. Lodewijks, R. Parmentier and P. Span (eds.), *Learning and Instruction.* Leuven/Oxford, Leuven University Press/Pergamon Press.

Eggan, P. D.; Kauchak, D. 1992. *Educational Psychology: Classroom Connections.* New York, Macmillan.

Elbers, E. 1991. The Development of Competence and Its Social Context. *Educational Psychology Review*, Vol. 3, No. 2, pp. 73–148.

Fischbein, E.; Deri, M.; Nello, M.; Marino, M. 1985. The Role of Implicit Models in Solving Problems in Multiplication and Division. *Journal of Research in Mathematics Education*, Vol. 16, pp. 3–17.

Fried, L. S.; Holyoak, K. J. 1984. Induction of Category Distributions: A Framework for Classification Learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, Vol. 10, pp. 234–57.

Gelman, R. 1978. Cognitive Development. *Annual Review of Psychology*, Vol. 29. Palo Alto, Calif., Annual Review, Inc.

——. 1982. Basic Numerical Abilities. In: R. J. Sternberg (ed.), *Advances in the Psychology of Human Intelligence*, Vol. 1. Hillsdale, N.J., Lawrence Erlbaum Associates.

——. 1991. Epigenetic Foundations of Knowledge Structures: Initial and Transcendent Constructions. In: S. Carey and R. Gelman (eds.), *The Epigenesis of Mind: Essays on Biology and Cognition*, pp. 293–322. Hillsdale, N.J., Lawrence Erlbaum Associates.

Gelman, R.; Greeno, J. 1989. On the Nature of Competence. In: L. B. Resnick (ed.), *Knowing, Learning, and Instruction.* Hillsdale, N.J., Lawrence Erlbaum Associates.

Gelman, R.; Massey, C.; McManus, M. 1991. Characterizing Supporting Environments for Cognitive Development: Lessons from Children in a Museum. In: J. M. Levine, L. B. Resnick and S. D. Teasley (eds.), *Perspectives on Socially Shared Cognition*, pp. 226–56. Washington, D.C., American Psychological Association.

Constructivist theories of cognitive development hold that learners are actively engaged in selecting and

interpreting inputs from their environments. This approach therefore makes it possible that novices will ignore or misinterpret inputs presented to them in instructional settings because they do not share the purpose intended by those who design instructional materials. This paper applies the constructivist perspective to an exploration of learning in a children's museum.

A series of studies is presented in which successive adjustments are made to an exhibit on causal reasoning that is based on a simple principle of physics. The exhibit consisted of two identical large cylinders wrapped with clear plastic tubing through which rubber balls can be rolled. The tubing was wrapped around one cylinder three times and around the other cylinder five times. The child's task was to predict which of two balls, dropped simultaneously into the two tubes, would exit the tubing first. In the original exhibit, instructional information was provided only on signs. The adults accompanying the children rarely read the signs to their preliterate charges. Consequently, the children failed to make predictions or to use the apparatus in a way that allowed them to make the relevant comparisons. A series of additions and changes were made that modified the exhibit. In the final version, a computer which provided both visual and auditory demonstrations, questions and instructions was incorporated into one of the cylinders. These changes resulted in an increase in adult involvement. With the greater levels of adult interaction, the children were found to produce more scientific talk, to make predictions and to perform the relevant experiments.

Gelman, R.; Meck, E. 1986. The Notion of Principle: The Case of Counting. In: J. Heibert (ed.), *The Relationship between Procedural and Conceptual Competence.* Hillsdale, N.J., Lawrence Erlbaum Associates.

Gibson, E. J.; Spelke, E. S. 1983. The Development of Perception. In: J. H. Flavell and E. M. Markman (eds.), *Handbook of Child Psychology,* pp. 1–76. New York, Wiley.

Glaser, R. 1991. The Maturing of the Relationship between the Science of Learning and Cognition and Educational Practice. *Learning and Instruction,* Vol. 1, pp. 129–44.

Goldenberg, C.; Gallimore, R. 1991. Changing Teaching Takes More Than a One-shot Workshop. *Educational Leadership,* Vol. 49, No. 3, pp. 69–72.

Goodnow, J. J.; Collins, W. A. 1990. *Development According to Parents: The Nature, Sources, and Consequences of Parents' Ideas.* Hillsdale, N.J., Lawrence Erlbaum Associates.

Goswami, U.; Brown, A. L. 1990. Higher-order Structure and Relational Reasoning: Contrasting Analogical and Thematic Relations. *Cognition,* Vol. 36, pp. 207–26.

Goswami and Brown's findings dispute the claim that children can only succeed in solving analogies when they can use low-level associative reasoning strategies. The authors performed two studies in which higher-level relational responses were pitted against lower-level associative responses and mere appearance matches. In each of the experiments, 4- to 9-year-olds were required to complete a pictorially presented analogy of the a:b:c:? form by choosing the appropriate picture to complete the sequence. Children of all ages were able to solve the analogies. However, performance improved with age. Goswami and Brown's results show young children to be more competent than has been shown in other studies of children's analogical problem-solving. They attribute this difference to their use of pictures instead of verbal presentations of the problems. Goswami and Brown suggest that analogies are a potentially effective tool for learning for even very young children.

Greenfield, P. M. 1984. A Theory of the Teacher in the Learning Activities of Everyday Life. In: B. Rogoff and J. Lave (eds.), *Everyday Cognition,* pp. 117–38. Cambridge, Mass., Harvard University Press.

Griffin, S.; Case, R.; Capodilupo, A. 1992. Rightstart: A Program Designed to Improve Children's Performance in Early Mathematics by Developing the Central Conceptual Structure on which this Performance Depends. In: S. Strauss (ed.), *Development and Learning Environments.* Norwood, N.J., Ablex Publishing Corp.

Griffin et al. discuss the Rightstart programme and its effectiveness as a tool for helping children develop the quantitative conceptual structures essential for the acquisition of more advanced mathematical concepts (for example, addition and subtraction) during the first year of formal schooling.

Griffin et al. conducted a study to answer four questions regarding Rightstart. The first question was whether or not the programme would be effective in the development of the 'central dimensional structure' (p. 12). The second was how effective Rightstart would be in comparison to other instructional programmes. The researchers also questioned whether instruction from Rightstart would help children transfer knowledge to other quantitative tasks. Finally, they were interested in how children who had been in the Rightstart programme would do in the first-grade setting (where instruction in arithmetic is minimal).

Portuguese kindergarten children in Toronto participated in the study. Subjects were placed into one of three programmes: (1) the Rightstart programme (experimental group); (2) a traditional early mathematics programme (control group A); and (3) a reading readiness programme (control group B). The groups differed in the amount of number training their members received. Participants in the Rightstart programme received the most extensive number training of all three groups. Children in control group A received training on some, but not all of the number components presented in the experimental condition. Children in control group B did not receive any number training.

Programme effectiveness was measured as the percentage of children within a group who could perform at the first-grade level. The results indicated that the Rightstart programme was more effective than either of the other two programmes at improving children's

performance to the first-grade level. The majority of children in the experimental group demonstrated knowledge suggesting the development of a central conceptual structure, while only a minority of children who had been in the control groups demonstrated comparable performance. In addition, more children in the Rightstart programme transferred acquired knowledge to novel tasks, in comparison with children from both control groups.

The second study differed from the first in only two ways. Subjects were from various schools in the United States and some modifications had been made to the Rightstart programme. The results again indicated the effectiveness of the experimental treatment. Regardless of school and cultural background, the proportion of children who demonstrated knowledge which implied a central conceptual structure and transferred acquired knowledge to a novel task was greater in the Rightstart programme than in the other two programmes.

Halford, G. S. 1989. Cognitive Processing Capacity and Learning Ability: An Integration of Two Areas. *Learning and Individual Differences,* Vol. 1, pp. 125–53.

——. 1990. *Children's Understanding: The Development of Mental Models.* Hillsdale, N.J., Lawrence Erlbaum Associates.

Hatano, G. 1988. Social and Motivational Bases for Mathematical Understanding. In: G. G. Saxe and M. Gearhart (eds.), *Children's Mathematics,* Vol. 41: *New Directions for Child Development,* pp. 55–70. San Francisco, Jossey-Bass.

Hatano, G.; Inagaki, K. 1986. Two Courses of Expertise. In: H. Stevenson, H. Azuma and K. Hakuta (eds.), *Child Development and Education in Japan,* pp. 262–72. San Francisco, Freeman.

Hatano and Inagaki discuss the role of contextual factors in developing two forms of expertise, adaptive and routine. Both forms of expertise refer to the ability to perform procedural skills efficiently. Adaptive experts, however, perform these skills with understanding. They are able to explain the principles underlying the skills they perform and they can modify their procedures to meet the requirements of their tasks. Routine experts are highly efficient but they can apply their skills only to a limited range of problems. Their problem-solving lacks flexibility and adaptability.

Adaptive expertise is encouraged when people are exposed to variation in the repeated application of a given procedure. Variation may be built into a system or may be the result of one's drive to experiment. Situations in which performance efficiency is rewarded on the basis of external evaluation and the focus is on the timely completion of the task will instead result in the development of routine expertise.

An example of the way in which the different types of expertise are encouraged is provided by a study in which college students were asked to translate a letter from English to Japanese. Some students were led to expect external evaluation while others were not. The students who expected their work to be evaluated spent more time on the task, verified their translations by more frequently referring to a dictionary, and produced more literal and less elaborate translations. The students in the other group were more likely to draw the inferences required fully to understand the text.

——. 1987. Everyday Biology and School Biology: How Do They Interact? *Quarterly Newsletter of the Laboratory of Comparative Human Cognition,* Vol. 4, pp. 120–8.

——. 1991. Sharing Cognition through Collective Comprehension Activity. In: J. M. Levine, L. B. Resnick and S. D. Teasley (eds.), *Perspectives on Socially Shared Cognition,* pp. 226–56. Washington, D.C., American Psychological Association.

Hatano, G.; Miyake, N. 1991. What Does a Cultural Approach Offer to Research on Learning? *Learning and Instruction,* Vol. 1, pp. 273–81.

This paper discusses the role of culture in learning and raises the question of why learning researchers have adopted an acultural approach to research. The authors argue that culture impacts directly on learning in two ways. First, other people and artefacts play an important role in learning and in the development of mind and, second, what occurs in the micro environment in which individual learning is observed is affected by a larger context, at both community and global levels. In spite of this, the academic tradition of learning research ignores the methodological implication of the effect of culture on learning. In an effort to control the experimental setting, basic research on learning is conducted in an artificial environment that is significantly different from the context in which it takes place. For example, research has shown that strategies that allow young children to solve simple mathematical problems are often acquired in informal settings. However, these problem-solving strategies do not transfer to classroom situations where the children are expected to solve mathematics problems using more traditional paper and pencil methods.

Heath, S. E. 1981. Questioning at Home and School: A Comparative Study. In: Spindler G. (ed.), *Doing Ethnography: Educational Anthropology in Action.* New York, Holt, Rinehart & Winston.

Heckhausen, H. 1982. The Development of Achievement Motivation. In: Hartup, W. W. (ed.), *Review of Child Development Research.* Chicago, University of Chicago Press.

Holyoak, K. J. 1991. Symbolic Connectionism: Toward Third-generation Theories of Expertise. In: K. A. Ericsson and J. Smith (eds.), *Toward a General Theory of Expertise: Prospects and Limits,* pp. 301–35. Cambridge, Cambridge University Press.

Holyoak, K. J.; Spellman, B. A. 1993. Thinking. *Annual Review of Psychology,* Vol. 44, pp. 265–315.

Hyde, T. S.; Jenkins, J. J. 1973. Recall for Words as a Function of Semantic, Graphic, and Syntactic Orienting Tasks. *Journal of Verbal Learning and Verbal Behavior,* Vol. 12, pp. 471–80.

Kalnins, I. V.; Bruner, J. S. 1973. The Coordination of Visual Observation and Instrumental Behavior in Early Infancy. *Perception,* Vol. 2, pp. 307–14.

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Karmiloff-Smith, A. 1992. *Beyond Modularity: A Developmental Perspective on Cognitive Science.* Cambridge, Mass., MIT Press/Bradford Books.

Karmiloff-Smith, A.; Inhelder, B. 1974/75. If You Want to Get Ahead, Get a Theory. *Cognition,* Vol. 3, pp. 195–212.

Keil, F. 1986. The Acquisition of Natural Kind and Artefact Terms. In: A. Marras and W. Demopoulos (eds.), *Conceptual Change.* Norwood, N.J., Ablex Publishing Corp.

Keil argues that between the ages of 4 and 10 years children's basic knowledge of biology is acquired and restructured. Children's early biological concepts are based on their interpretations of surface phenomena. They reason in terms of clusters of surface features rather than the essences of things that appear in nature. Older children instead base their reasoning about natural phenomena on deeper, underlying characteristics that do not necessarily correlate with surface features.

Keil performed two experiments to test these assumptions. In his first experiment, 5- and 9-year-olds were asked to identify an animal based on a description of its behaviours and appearance. For example, a skunk was described as something that was 'active at night and squirted smelly stuff when it was attacked or frightened, and so on'. Children were good at identifying the described object based on its description and its picture. The children were then told that the animal's 'parents had been raccoons, that its babies had been raccoons, that its heart, brain and blood were like the heart, brain and blood of raccoons'. Children were again asked to identify the animal. The younger children continued to base their identifications on the animal's surface characteristics. Thus, they continued to call the animal a skunk. The older children instead claimed that the animal was a raccoon that simply looked like a skunk.

In Keil's second study, children were shown similar pictures (for example, a skunk), but this time they were told that the original animal's fur had been shaven off and replaced with raccoon fur. They were further told that the original animal had been made fatter and that its original tail had been removed and replaced with one from another animal. The resulting animal looked like a raccoon. When asked to identify the resulting picture, 5-year-olds again relied on surface features, this time identifying the animal as a raccoon. The 9-year-olds said the animal looked like a raccoon but it was really a skunk. Thus, Keil concluded that the 9-year-olds based their interpretations on the essence of the animal rather than its appearance.

The use of control items in the study demonstrated that all children tended to reason about artefacts in the way that the 5-year-olds reasoned about natural kinds. For example, a coffee-pot that was altered to resemble a bird-feeder was identified as a bird-feeder by both 5- and 9-year-old children. This result shows that older children distinguish between artefacts and natural kinds. Older children realize that artefacts which have been altered to take on the characteristics of another artefact can be identified as what they have been changed to because they do not share the same types of biological origins as do natural kinds.

——. 1989. *Concepts, Word Meanings, and Cognitive Development.* Cambridge, Mass., MIT Press.

Kitcher, P. 1982. *The Nature of Mathematical Knowledge.* New York, Oxford University Press.

Kuhn, T. S. 1970. *The Structure of Scientific Resolutions.* 2nd ed. Chicago, University of Chicago Press.

Lampert, M. 1986. Knowing, Doing and Teaching Multiplication. *Cognition and Instruction,* Vol. 3, pp. 305–42.

Lave, J. 1977. Cognitive Consequences of Traditional Apprenticeship Training in West Africa. *Anthropology and Education Quarterly,* Vol. 8, pp. 177–80.

Lave J. L.; Wenger, E. 1991. *Situated Learning: Legitimate Peripheral Participation.* Cambridge/New York, Cambridge University Press.

This book explores different notions and examples of apprenticeship from the metaphorical invocation to investigating the historical forms. Lave and Wenger argue that apprentices learn to think, argue, act and interact by engaging in activities through legitimate peripheral participation with masters, people who are considered expert in the skills related to the activity. Initially the apprentices' participation in the tasks is partial and limited in scope. As skills develop, the work increases in both complexity and scope. The culture of the society determines the exact definition and role of the apprentices.

The authors examine five diverse examples of apprenticeship: midwives, tailors, quartermasters, meatcutters and Alcoholics Anonymous members (AA: a self-help group for recovering alcoholics). The master role varies greatly from one example to the next and structure is dictated by the environment or work task and not by the teacher/master. This structure results in emphasis being placed on the curriculum and not on the individual teacher. For example, in the AA apprenticeship, a high emphasis is placed on 'reconstruction of identity', and stories are used to provide information. Here the two marks of apprenticeship are models/stories. Stories provide criteria for full membership. Alcoholics, in telling their stories, provide an explicit external model which allows the new members to reflect by comparing themselves to the model. Older members serve as masters by providing the model and reinforcing appropriate aspects of the new members' stories by picking up on certain themes while ignoring other aspects which are not appropriate.

Lave and Wenger develop a social anthropological theory of learning activities and environments where the emphasis is shifted away from the individual as learner to the learner as participant in a social world.

Linn, M.; Gelman, R. 1987. On the Use of Hands-on Materials in Science Class. *Continuum – Newsletter of the Philadelphia Renaissance in Science and Mathematics,* pp. 3–4.

McCloskey, M. 1983. Naive Theories of Motion. In: D. Gentner; A. L. Stevens (eds.), *Mental Models.* Hillsdale, N.J., Lawrence Erlbaum Associates.

McCloskey, M.; Kargon, R. 1988. The Meaning and Use of Historical Models in the Study of Intuitive Physics. In: S. Strauss (ed.), *Ontogeny, Phylogeny, and Historical Development.* Norwood, N.J., Ablex Publishing Corp. (Human Development Series, Vol. 2.)

McDonald, M. A.; Sigman, M. D.; Espinosa, M. P. In press. Impact of a Temporary Food Shortage on Children and Their Mothers. *Child Development.* (Special Issue on Children and Poverty edited by C. Garcia Coll.)

McGuiness, C.; Nisbet, J. 1991. Teaching Thinking in Europe. *British Journal of Education,* Vol. 61, pp. 174–86.

Mandler, J. M. 1984. *Stories, Scripts, and Scenes: Aspects of Schema Theory.* Hillsdale, N.J., Lawrence Erlbaum Associates.

Medin, G. L. 1989. Concepts and Conceptual Structures. *American Psychologist,* Vol. 44, pp. 1469–81.

Murphy, G. L.; Medin, D. L. 1985. The Role of Theories in Conceptual Coherence. *Psychological Review,* Vol. 92, pp. 289–316.

Nesher, P.; Sukenik, M. 1991. The Effect of Formal Representation on the Learning of Rational Concepts. *Learning and Instruction,* Vol. 1, pp. 161–75.

Newell, A.; Simon, H. A. 1972. *Human Problem Solving.* Hillsdale, N.J., Lawrence Erlbaum Associates.

O'Connor, M. C. 1991. Negotiated Defining: Speech Activities and Mathematics Literacies. Unpublished manuscript, Boston University and the Literacies Institute. (Mimeo.)

O'Connor presents an example of an attempt to immerse students in the discourse practices of the mathematics discipline. She assumes that students will only be able to understand the discourse practices of the mathematics discipline when they enter into the practice of that discipline. Comprehension of the specialized linguistic patterns of a discipline is considered necessary for the development of conceptual, factual and procedural learning as well as an understanding of the beliefs and values of the field.

Classroom discourse is thought to support students' transitions from everyday to scientific uses of language by increasing students' access to such language and by providing the support of a teacher who can orchestrate speech activity so that it is compatible with practice within the discipline. O'Connor notes that a teacher's subject-matter knowledge is crucial if he or she is to provide this form of guidance effectively.

Orr, E. W. 1989. *Twice as Less: Does Black English Stand between Black Students and Success in Math and Science?* New York, W.W. Norton & Co.

Palincsar, A. S. 1989. Less Charted Waters. *Educational Researcher,* Vol. 18, No. 4, pp. 5–7.

The article responds to a paper on situated cognition which argues for learning and conceptual development through enculturated activities. Three main virtues of situated cognition are outlined: learning in a meaningful context, aiding students to relate new information to a meaningful framework and giving students a sense of agency in their learning.

Perret-Clermont, A.-N.; Schaubler-Leoni, M. L. 1989. Social Factors in Learning and Teaching: Towards an Integrative Perspective. *International Journal of Educational Research,* Vol. 13, pp. 575–80.

Reber, A. S. 1989. Implicit Learning and Tacit Knowledge. *Journal of Experimental Psychology: General,* Vol. 118, pp. 219–35.

Resnick, L. B. 1989. Developing Mathematical Knowledge. *American Psychologist,* Vol. 44, No. 2, pp. 162–9.

Researchers from many disciplines assume that knowledge, specifically mathematical knowledge, is actively constructed by learners of all ages. Evidence suggests that even infants have prelinguistic, number knowledge which allows them to discriminate small set sizes and to make comparative size judgements. Preschool children use their developing language skills to express quantitative information in non-numerical form, using terms such as 'smaller' and 'lots'. Children of this age understand basic addition, subtraction, even conservation of number. Simple part-whole judgements can also be made. Principled counting skills also develop in the preschool years. As an exact measurement system, counting skills are integrated with non-numerical quantitative abilities to make more precise mathematical judgements. Although the development of these basic numerical abilities seems to be universal, rates of acquisition may vary as a function of the extent to which mathematical skills are part of everyday life.

Exactly how *mathematics knowledge* develops during the elementary-school years is difficult to determine, given the increased number of skills to be studied and the not-fully-understood effect of schooling. Certain abilities emerge without specific tutoring, including an intuitive understanding of commutativity and the complementarity of the addition and subtraction procedures. Studies indicate that understanding of additive composition occurs universally and without schooling, allowing, for example, street vendors in Brazil to quickly solve mathematical problems (such as the price of 10 coconuts if one costs 45 cruzeros) in the market place. If children intuitively know so much about mathematical concepts, why do so many have trouble with mathematics in school? The problem seems to be that the focus on mathematics as a formal symbol system does not map well onto what children already know about the to-be-taught concepts. Despite arguments on how to teach mathematics most effectively, many now agree that children's own counting methods may provide a bridge to more advanced conceptual knowledge and therefore should not be discouraged in the school setting.

Rogoff, B. 1990. *Apprenticeship in Thinking.* New York, Oxford University Press.

Apprenticeship (or learning from others) takes different forms depending on the task. Important characteristics of apprenticeship include shared problem-solving, establishment of routine activities between participants, explicit shared communication and a supportive structure of novices' efforts. In guided participation, the structuring of the task, the social interaction, and roles of the children and their caregivers

are interrelated within the zone of proximal development.

A second related major theme highlighted by Rogoff is the consideration of an event as a unit of analysis. From a sociohistorical perspective, the basic unit of analysis no longer focuses on the processes of the sole individual; rather, it is processes of sociocultural activities involving active participation of people in socially constituted practices that are examined.

Rogoff's discussions of Piaget and Vgotsky lead to another major theme of her book: how learning from masters is unique and different from learning from peers. The author contrasts Vgotsky's expert support/apprenticeship (through examination of the social tool of language) with Piaget's 'cognitive conflict between peers' (through examination of transformations in reasoning processes).

Salomon, G.; Globerson, T. 1987. Context-dependent Effects on Analogical Transfer. *Memory and Cognition*, Vol. 14, No. 5, pp. 442–49.

Saxe, G. B.; Gearhart, M. 1988. Transfer of Learning across Cultural Practices. *Cognition and Instruction*, Vol. 6, No. 4, pp. 335–50.

Saxe, G. B.; Posner, J. 1982. The Development of Numerical Cognition: Cross-cultural Perspectives. In: H. P. Ginsburg (ed.), *The Development of Mathematical Thinking*. New York, Academic Press.

Schieffelin, B. B.; Ochs, E. 1986. *Language Socialization across Cultures*. Cambridge, Cambridge University Press.

Schmidt, R. A.; Bjork, R. A. 1992. New Conceptualizations of Practice: Common Principles in Three Paradigms Suggest New Concepts for Training. *Psychological Science*, Vol. 3, No. 4, pp. 207–17.

Schoenfeld, A. H. 1987. What's All the Fuss About Metacognition? In: A. Schoenfeld (ed.), *Cognitive Science and Mathematics Education*, pp. 189–215. Hillsdale, N.J., Lawrence Erlbaum Associates.

Shatz, M.; Gelman, R. 1973. The Development of Communication Skills: Modifications in the Speech of Young Children as a Function of Listener. *Monographs of the Society for Research in Child Development*, Vol. 38, No. 5, Serial No. 152.

Shaw, R.; Bransford, J. D. 1977. *Perceiving, Acting, and Knowing: Toward an Ecological Psychology*. Hillsdale, N.J., Lawrence Erlbaum Associates.

Shiffrin, R. A. 1988. Attention. In: R. C. Atkinson, R. J. Herrnstein, G. Lindzey and D. R. Luce (eds.), *Steven's Handbook of Experimental Psychology*, pp. 739–811. New York, W. J. Wiley.

Siegal, M. 1991. A Clash of Conversational Worlds: Interpreting Cognitive Development through Communication. In: L. B. Resnick, J. M. Levine and S. D. Teasley (eds.), *Perspectives on Socially Shared Cognition*, pp. 23–40. Washington, D.C., American Psychological Association.

This paper explores the notion that children may incorrectly answer questions posed by adults during experimental tasks because they do not share the purpose and context of the experimenters' question and not because of conceptual difficulties or limitations. In an effort to probe the child, conversation rules are often ignored in experimental settings and this results in ambiguous or incorrect responses from children. For example, children may change a correct answer simply because the previously answered question is repeated or they may misinterpret a question because the experimenter provides too little or too much information. The author examined children's performance on a variety of tasks used to assess cognitive development and concluded that the failure of the children frequently reported on these tasks was due to a lack of the conversational experience that would have allowed them to successfully interpret the experimenter's questions.

Siegler, R. S. 1991. *Children's Thinking*. 2nd ed. Englewood Cliffs, N.J., Prentice-Hall.

Sinha, S. 1982. Sociocultural Factors and the Development of Perceptual and Cognitive Skills. In: W. W. Hartup (ed.), *Review of Child Development Research*, pp. 441–73. Chicago, University of Chicago Press.

Smith, S. M.; Glenberg, A.; Bjork, R. A. 1978. Environmental Context and Human Memory. *Memory and Cognition*, Vol. 6, pp. 342–53.

Spiro, R. J.; Feltovich, P. J.; Coulson, R. L.; Anderson, D. K. 1989. Multiple Analogies for Complex Concepts: Antidotes for Analogy-induced Misconceptions in Advanced Knowledge Acquisition. In: S. Vosniadou and A. Ortony (eds.), *Similarity and Analogical Reasoning*, pp. 498–531. New York, Cambridge University Press.

Spiro, Feltovich, Coulson and Anderson suggest that while the use of simple analogies can assist a novice in gaining an initial understanding of a domain, the simplification of concepts presented in this manner may impede the acquisition of more complete understanding. The authors suggest two ways to avoid this problem. First, instructors must be aware of misleading aspects of individual analogies as well as the possibility that they will fail to allow a complete mapping to the target domain. Although an analogy may be misleading or incomplete in reference to a specific feature of a domain, it will often provide a piece of information that is not evident without its use. Spiro et al.'s second method of dealing with this problem takes the usefulness of such faulty analogies into account. Their second approach to combating problems due to the oversimplified application of analogies is to employ the use of multiple analogies that collectively reflect the complexity of the domain under study and that can serve to compensate for any misleading aspects of a given analogy. The use of integrated sets of analogies is also effective in that it allows students to connect newly presented concepts to knowledge they have previously acquired.

Starkey, P.; Spelke, E. S.; Gelman, R. 1990. Numerical Abstraction by Human Infants. *Cognition*, Vol. 36, pp. 97–127.

Steele, C. M. 1992. Race and the Schooling of Black Americans. *Atlantic Monthly*, Vol. 269, pp. 68–79.

At some time in their academic career, 70 per cent of all black Americans at four-year colleges drop out. More than half of black college students fail to com-

plete their degree work. The author identifies stigma as the cause of this crisis and the endemic devaluation many blacks face in our society and in our schools.

American schooling fails to instil in blacks the belief that school achievement can be a basis of self-esteem. Racial devaluation at school comes from the society in general and not just from the strongly racially prejudiced. Blacks disidentify from scholastic achievement as a reaction to a double vulnerability, a risk of confirming a particular incompetence and a risk of confirming a suspected racial inferiority.

'Wise' schooling, that is, schooling that sees the value and promise in black students and acts on it, should undermine vulnerability and improve achievement. 'Unwise' schooling may include a remedial orientation toward education of blacks, an orientation which puts abilities under suspicion and which foments greater racial vulnerability.

Schooling must focus more on reducing the vulnerabilities that block identification with achievement. Four conditions are fundamental: (1) the student must feel valued by the teacher for his or her potential as a person; (2) personal fulfilment, not remediation, should guide the education of these students; (3) racial integration is a generally useful element, if not a necessity; (4) the particulars of black life and culture must be present in the mainstream curriculum of American schooling.

Stevenson, H. W.; Stigler, J. W. 1992. *The Learning Gap: Why Our Schools are Failing and What We Can Learn from Japanese and Chinese Education.* New York, Summit Books.

Stevenson and Stigler address the question of how the United States might improve education by examining the education systems of other cultures, specifically Japan and China. They conclude that the United States' educational crisis will only be resolved when institutions at all levels (family, schools, federal, state and local governments, etc.) become deeply involved in the issue. Additionally, an effective solution must address multiple variables, including the beliefs and attitudes of students and parents toward the educational process, identification of the factors that motivate students and specific educational practices.

Comparisons of children in the United States with children in China and Japan indicate that American students' scores on achievement tests fall below those of their counterparts in many subjects, especially in math and science. Stevenson and Stigler note that the poorer achievement of the American students is not due to intellectual deficiencies, but is the result of differences in factors related to contributions from both the home and school to academic performance.

Stigler, J. W.; Nussbaum, H. C.; Chalip, L. C. 1988. Developmental Changes in Speed of Processing: Central Limiting Mechanism or Skill Transfer? *Child Development,* Vol. 59, pp. 1144–53.

Stipek, D. J. 1988. *Motivation to Learn: From Theory to Practice.* Boston, Allyn & Bacom.

Tharp, R. G.; Gallimore, R. 1989. Rousing Schools to Life. *American Educator,* 20–25 June, pp. 46–52.

Tharp and Gallimore discuss the limitations of using recitation as a method of classroom instruction. They suggest that methods that stress the importance of recalling facts presented in the text are not as effective for student learning as methods that draw on students' experiences. Recitation methods encourage students to take a passive role in the learning process. Conversational methods of instruction instead promote active participation as students attempt to relate material presented in the classroom to events in their own lives. The authors apply this concept in their use of the 'instructional conversation'. This instructional technique focuses on assisted performance. Expert teachers continually assess their students' performance levels and adjust their degree of guidance accordingly. Eventually, students are expected to perform the functions of the adult assistant for themselves.

A major challenge involved in implementing this instructional method is training teachers to become successful moderators of classroom discussion. Teachers must have a deep understanding of the subject-matter they are teaching if they are to guide students' learning effectively. Although the point of a story presented in a reading lesson may appear to be obvious, teachers must understand the story to the degree that they can recognize multiple opportunities to link story concepts to ideas that students bring to the lesson. They must also learn when it will be most beneficial to discuss a point of information and when it will be better to simply teach a concept directly to their students.

Moving away from recitation methods requires teachers to do much more than simply decide to adopt a new technique. The effective implementation of instructional conversations requires much effort, adjustment and practice on the part of the teacher.

Verschaffel, L.; De Corte, E. In press. A Decade of Research on Word-problem Solving in Leuvan: Theoretical, Methodological, and Practical Outcomes. *Educational Psychology Review.*

Voigt, L. A. 1989. The Social Constitution of the Mathematics Province – A Microethnographical Study in Classroom Interaction. *Quarterly Newsletter of the Laboratory of Comparative Human Cognition,* Vol. 11, Nos. 1–2, pp. 27–34.

Patterns of interaction between teacher and students are important elements of the classroom culture. This study examines the nature of classroom social interaction used in mathematics education in Germany. One typical routine found in German classrooms is a 'staging pattern', utilized by teachers to introduce new mathematics concepts to students. A 'staging pattern', identified by the author, is one in which teachers elicit students' responses to questions about relevant everyday experiences and non-academic ideas that can be connected to the mathematics lesson. For example, the teacher may question students about their experiences with everyday gambling games (lottery) and then connect their responses to a lesson on probability. This teaching strategy serves as a starting point for discussion on new mathematics

topics. The teacher's routines lead students' ideas towards the theme of the mathematical concept to be presented.

The author suggests many advantages for the establishment of this initial teacher–student routine in mathematics lessons.

Vygotsky, L. S. 1978. *Mind in Society: The Development of Higher Psychological Processes.* Cambridge, Mass., Harvard University Press.

Walker, E. 1982. Intermodal Perception of Expressive Behaviors by Human Infants. *Journal of Experimental Child Psychology,* Vol. 33, pp. 514–35.

Weisner, T. S. 1984. Ecocultural Niches of Middle Childhood. In: W. A. Collins (ed.), *Development during Middle Childhood: The Years from Six to Twelve.* Washington, D.C., National Academy Press.

Wheeler, D. D. 1970. Processes in Word Recognition. *Cognitive Psychology,* Vol. 1, pp. 59–85.

White, B. Y. 1991. Intermediate Causal Models: A Missing Link for Successful Science Education? In: R. Glaser (ed.), *Advances in Instructional Psychology,* Vol. 4. Hillsdale, N.J., Lawrence Erlbaum Associates.

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